Proceeding International Conference on Religion, Science and Education (2024) **3**, 741-749

Flood Susceptibility Mapping of Brebes Region Using Multi-Source Geospatial Data and Analytical Hierarchy Process (AHP)

Mohammad Obie Restianto*, Aris Poniman, Makmur Supriyatno
Sensing Technology Study Program, Faculty of Defense Science and Technology, Republic of Indonesia Defense University IPSC, Sentul Area, Citereup, Bogor, West Java, Indonesia.

Corresponding author*
obie.restianto@gmail.com

Abstract: Floods are the most frequent natural disasters in Indonesia. Brebes Regency is periodically threatened by flood disasters. With this disaster, flood susceptibility mapping is needed. This research uses the Analytical Hierarchy Process (AHP) weighting method and using multi-source geospatial data. There are 10 parameters used in this research: Topographic Wetness Index, Elevation, Slope, Precipitation, LULC, NDVI, Distance from river, Distance from road, Drainage density, and soil type. The results of this research show that Brebes Regency has a high flood susceptibility is 3.3%, moderate flood susceptibility is 46.39%, low flood susceptibility is 50.03%, and very low flood susceptibility is 0.23%.

Keywords: Flood, AHP.

Introduction

Floods are a natural occurrence that often manifest suddenly with an unpredictable frequency, except in regions that regularly experience annual flooding during the rainy season. This situation presents significant challenges in disaster mitigation and preparedness efforts. Some areas that routinely face annual floods during the rainy season may have developed various strategies and infrastructure to minimize the impact of these flood disasters. Nevertheless, it remains an urgent issue in many flood-prone areas (Matondang 2013). The consequences of these floods can be highly detrimental to the residents in these areas, including property damage, economic losses, and potential threats to human and animal safety. Therefore, a deeper understanding of the patterns and influencing factors of floods is crucial in reducing vulnerability and developing effective mitigation strategies to protect the populations living in flood-prone regions.

Floods are a natural disaster frequently occurring in Brebes Regency, Central Java, Indonesia, and have become a serious concern over the past few decades. The geographical and hydrological characteristics of the area, situated on low-lying land near the estuary of the Pemali River, contribute to the increased vulnerability to flooding. Furthermore, the rising intensity of rainfall due to climate change has added to the frequency and magnitude of flood events (Sutikno et al. 2021). Changes in land use, particularly deforestation and uncontrolled urbanization, have exacerbated the soil's absorption capacity and increased surface runoff, thus triggering more frequent and severe floods (Widodo et al. 2019).

This research aims to conduct a comprehensive assessment of the flood susceptibility in Brebes Regency by examining a set of criteria including the Topographic Wetness Index, elevation, slope, precipitation, land use/land cover (LULC), Normalized Difference Vegetation Index (NDVI), distance from rivers, distance from roads, drainage density, and soil types. Additionally, the research will leverage the Analytical Hierarchy Process (AHP) for weighting these criteria and Geographic

ISSN 2829-3355 | EISSN 2828-8467

Information Systems (GIS) for mapping processes. By integrating these methodologies, the research seeks to provide a detailed analysis of the factors contributing to flood susceptibility and to create a nuanced flood susceptibility map that can aid in effective planning and mitigation strategies.

Data and Methods

Study area

The focus of this research, Kabupaten Brebes, situated in the west segment of Central Java Province, Indonesia (Figure 1), is selected as the study area for its recurrent exposure to flood events. The topographical and hydrological dynamics of Brebes, including its river systems and land use patterns, contribute to its flood susceptibility. The region's flood history underscores the need for enhanced flood management strategies, which this study aims to support through comprehensive susceptibility mapping.

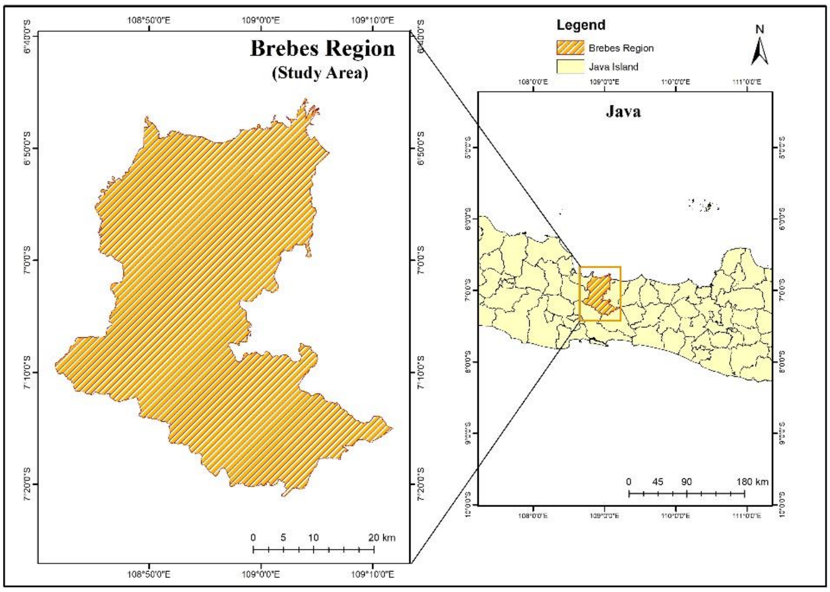

Figure 1. study area.

Data

This research using multi-source geospatial data (Table 1). The primary data used includes the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data, which was processed to generate the Topographic Wetness Index, elevation, slope, and drainage density maps. These variables are crucial for understanding the topographic factors that contribute to flood susceptibility. The Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) was processed into a precipitation map. This precipitation map was prepared by averaging rainfall data and applying the Inverse Distance Weighting (IDW) interpolation method to provide a spatially continuous precipitation field. Land Use and Land Cover (LULC) data was acquired from ESRI (Karra et al. 2021), which processes Sentinel-2 imagery into detailed LULC maps. Additionally, Landsat 8 imagery was utilized to produce the Normalized Difference Vegetation Index (NDVI). Local topographic maps from the Peta Rupa Bumi Indonesia (RBI) were processed to derive maps indicating the distance from rivers, the distance from roads, and soil types.

Table 1. Data for this research

Flood Causative Criterion	Data	Source
Topographic wetness index (TWI)	SRTM DEM	NASA Shuttle Radar Topography Mission (SRTM)(2013). Shuttle Radar Topography Mission (SRTM) Global. Distributed by OpenTopography. https://doi.org/10.5069/G9445JDF. Accessed: 2023-10-04
Elevation	SRTM DEM	NASA Shuttle Radar Topography Mission (SRTM)(2013). Shuttle Radar Topography Mission (SRTM) Global. Distributed by OpenTopography. https://doi.org/10.5069/G9445JDF. Accessed: 2023-10-04
Slope	SRTM DEM	NASA Shuttle Radar Topography Mission (SRTM)(2013). Shuttle Radar Topography Mission (SRTM) Global. Distributed by OpenTopography. https://doi.org/10.5069/G9445JDF. Accessed: 2023-10-04
Precipitation	Climate Hazards center InfraRed Precipitation with Station data (CHIRPS)	CHIRPS https://www.chc.ucsb.edu/data/chirps
LULC	Sentinel 2	ESRI https://livingatlas.arcgis.com/landcover/
NDVI	Landsat 8	USGS Earth Explorer https://earthexplorer.usgs.gov/
Distance from river	Peta Rupa Bumi Indonesia (RBI)	BIG http://tanahair.indonesia.go.id/portal-web/
Distance from road	Peta Rupa Bumi Indonesia (RBI)	BIG http://tanahair.indonesia.go.id/portal-web/
Drainage density	SRTM DEM	NASA Shuttle Radar Topography Mission (SRTM)(2013). Shuttle Radar Topography Mission (SRTM) Global. Distributed by OpenTopography. https://doi.org/10.5069/G9445JDF. Accessed: 2023-10-04
Soil type	Peta Rupa Bumi Indonesia (RBI)	BIG http://tanahair.indonesia.go.id/portal-web/

Metode

The Analytical Hierarchy Process (AHP), developed by Saaty (1980), is the methodological core of this research, employed to assess the flood susceptibility in the Brebes region. AHP is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It allows for the comparison of multi-criteria elements by pairwise comparisons and relies on the judgment of experts to derive priority scales. This process involves decomposing the decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analyzed independently. In the context of this study, the AHP was applied to evaluate various flood contributing factors such as the Topographic Wetness Index, elevation, slope, precipitation, land use/land cover (LULC), Normalized Difference Vegetation Index (NDVI), distance from rivers, distance from roads, drainage density, and soil types.

Table 2. Susceptibility Class Ranges and Ratings (Pandulu 2016; Tarkomo et al. 2021; Jamilah et al. 2021; Wirayuda et al. 2020)

Flood Causative Criterion	Unit	Class	Susceptibility Class Ranges and Ratings	Susceptibility Class Ratings
Topographic wetness index (TWI)	Level	-13.1 - -6.9	Very Low	1
		-6.9 - -3.5	Low	2
		-3.5 - 0.16	Moderate	3
		0.16 - 2.6	High	4
		2.6 - 9.3	Very high	5
Elevation	m	<2	Very High	5

		2.01 - 4	High	4
		4.01 - 6	Moderate	3
		6.01 - 9	Low	2
		9.01 - 25	Very Low	1
Slope	%	<0.93	Very Low	1
		0.93 - 2.14	Low	2
		2.14 - 3.74	Moderate	3
		3.74 - 6.56	High	4
		> 6.56	Very high	5
Precipitation	mm/year	> 3000	Very High	5
		2501 - 3000	High	4
		2001 - 2500	Moderate	3
		1501 - 2000	Low	2
LULC	Level	Water Body	Very High	5
		Agriculture Land	High	4
		Settlement	Moderate	3
		Barren Land	Low	2
		Vegetation	Very Low	1
NDVI	Level	-1 - -0.03	Very High	5
		-0.03 - 0.15	High	4
		0.15 - 0.25	Moderate	3
		0.25 - 0.35	Low	2
		0.35 - 1	Very Low	1
Distance from river	m	0 - 100	Very High	5
		100 - 200	High	4
		200 - 500	Moderate	3
		500 - 1000	Low	2
		>1000	Very Low	1
Distance from road	m	0 - 25	Very High	5
		26 - 50	High	4
		51 - 100	Moderate	3
		101 - 150	Low	2
		>150	Very Low	1
Drainage density	m/Km	0-86	Very Low	1
		87 - 170	Low	2
		180 - 260	Moderate	3
		270 - 350	High	4
Soil type	Level	Aluvial	Very High	5
		Latosol	High	4
		Mediteran	Moderate	3
		Grumosol	Low	2
		Regosol, Litosol	Very Low	1

Results and Discussion

Results and Discussion should be written as a series of connecting sentences, however, for manuscript with long discussion should be divided into subtitles. Results should be clear and concise.

Result

The outcome of the Analytical Hierarchy Process (AHP) weighting is presented in Figure 2, allocating the following weights to each factor: Topographic Wetness Index (TWI) at 13.78%, elevation at 12.07%, slope at 9.90%, precipitation at 13.45%, Land Use and Land Cover (LULC) at 6.62%, Normalized Difference Vegetation Index (NDVI) at 5.87%, distance from rivers at 14.08%, distance from roads at 5.59%, drainage density at 9.32%, and soil types at 9.32%. These weights reflect the relative contribution of each factor to flood susceptibility in the study area. The distance from rivers received the highest weight, indicating its significant influence on flood potential, followed by TWI and precipitation, which also have a substantial impact on determining the region's vulnerability to flooding. Conversely, LULC and NDVI are assigned lower weights, depicting their lesser role in contributing to flood risk. These AHP-derived weights will be utilized to develop a flood susceptibility map.

Matrix		TWI 1	Elevation 2	Slope 3	Precipitation 4	LULC 5	NDVI 6	Distance from river 7	Distance from road 8	Drainage density 9	Soil type 10	normalized principal Eigenvector
TWI	1	1	1	1	1	3	5	1	3	1	1	13.78%
Elevation	2	1	1	1	1	2	3	1	3	1	1	12.07%
Slope	3	1	1	1	1	3	1	1/2	1	1	1	9.90%
Precipitation	4	1	1	1	1	3	2	2	3	1	1	13.45%
LULC	5	1/3	1/2	1/3	1/3	1	1	1/3	3	1	1	6.62%
NDVI	6	1/5	1/3	1	1/2	1	1	1/5	1	1	1	5.87%
Distance from river	7	1	1	2	1/2	3	5	1	3	1	1	14.08%
Distance from road	8	1/3	1/3	1	1/3	1/3	1	1/3	1	1	1	5.59%
Drainage density	9	1	1	1	1	1	1	1	1	1	1	9.32%
Soil type	10	1	1	1	1	1	1	1	1	1	1	9.32%

Figure 2. The result of AHP *Weighting*.

The mapping results for the Topographic Wetness Index (TWI) and Elevation are displayed in Figure 3. The Slope and Precipitation data are displayed in Figure 4, while the Land Use and Land Cover (LULC) and Normalized Difference Vegetation Index (NDVI) are displayed in Figure 5. Distances from rivers and roads are displayed in Figure 6, and the mapping of Drainage Density and Soil Types is provided in Figure 7. These figures collectively exhibit the spatial distribution and interaction of the physical and environmental factors that contribute to the flood susceptibility assessment in the study area.

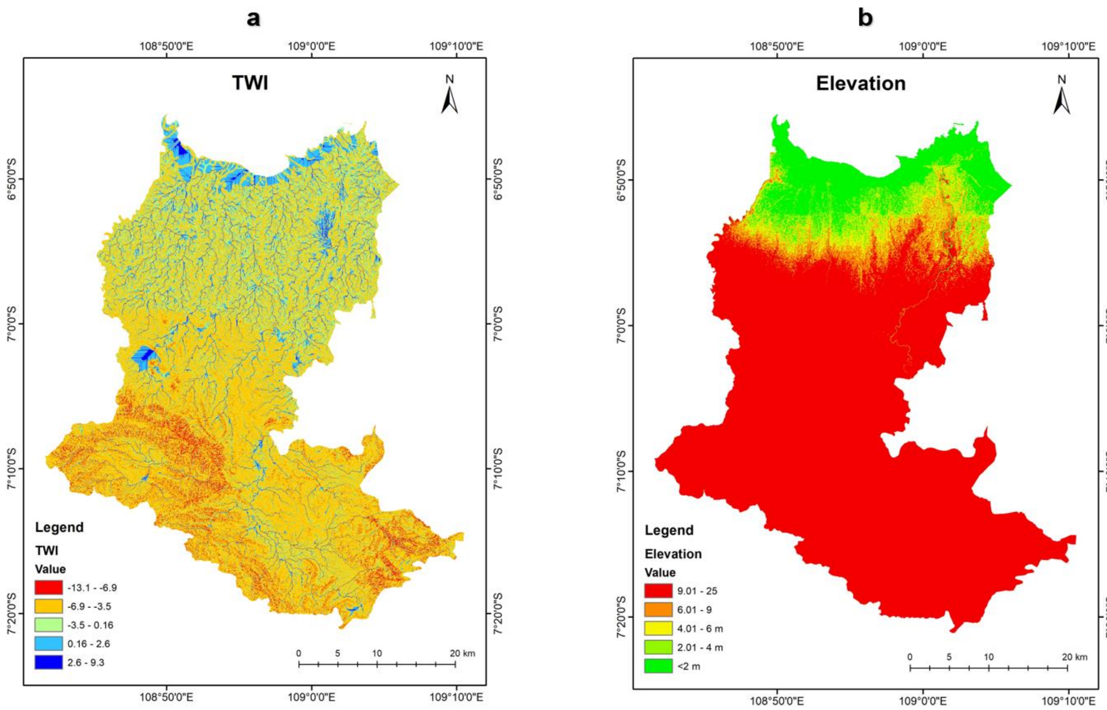

Figure 3. a) TWI, b) Elevation

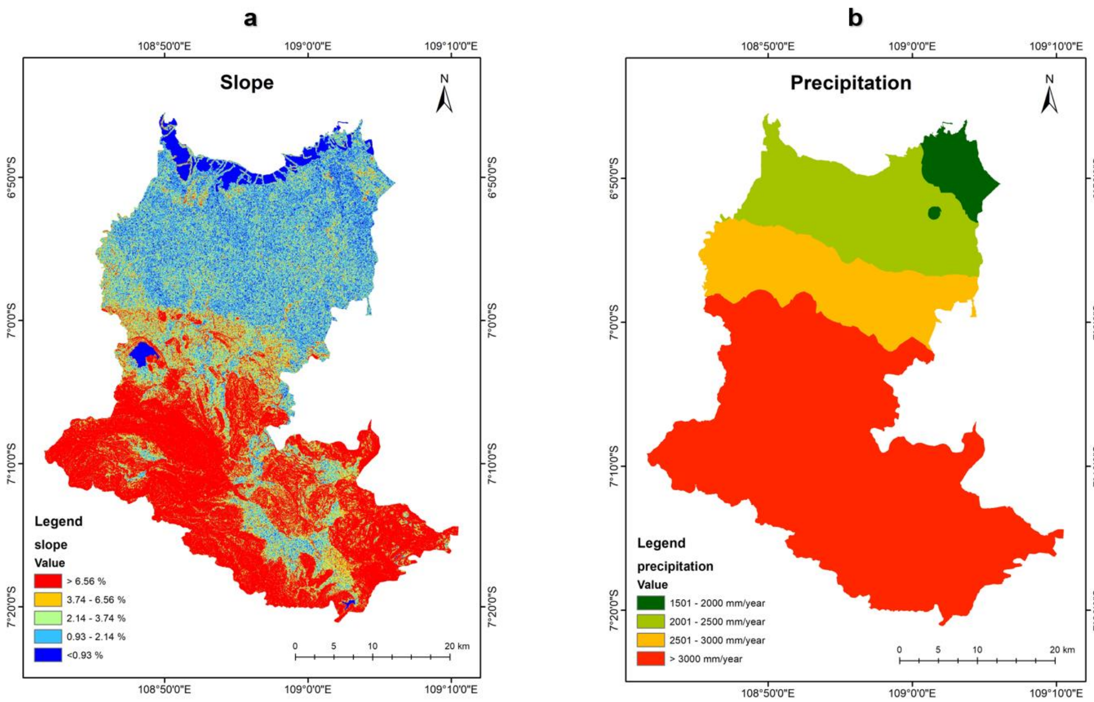

Figure 4. a) Slope, b) Precipitation

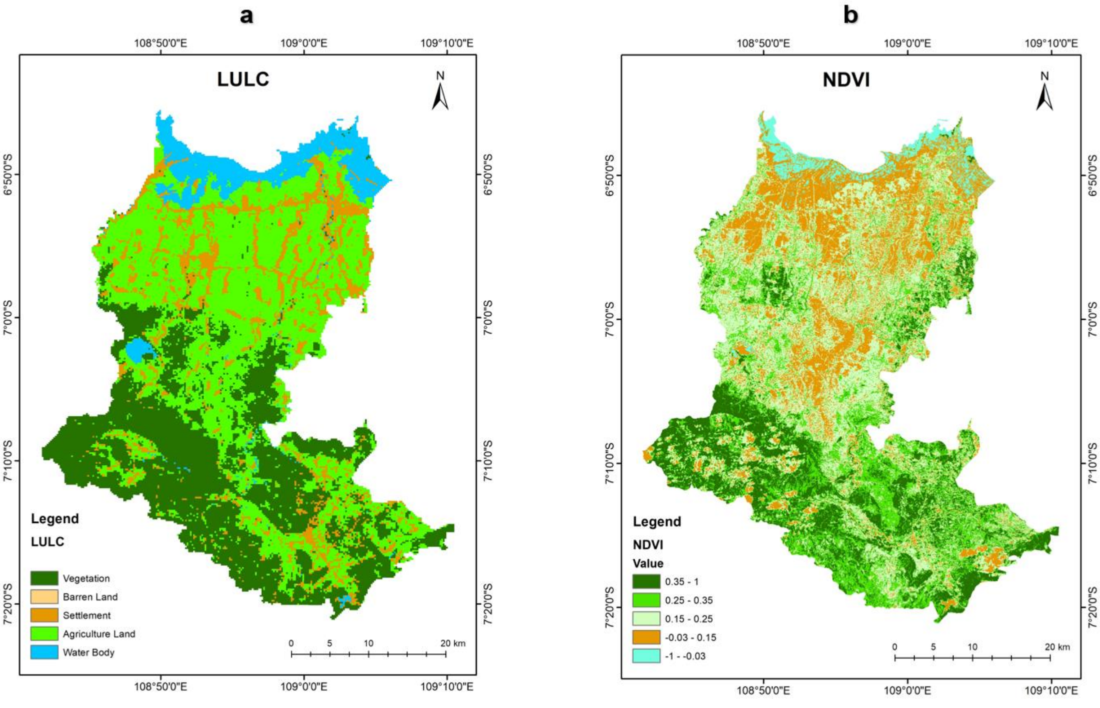

Figure 5. a) LULC, b) NDVI

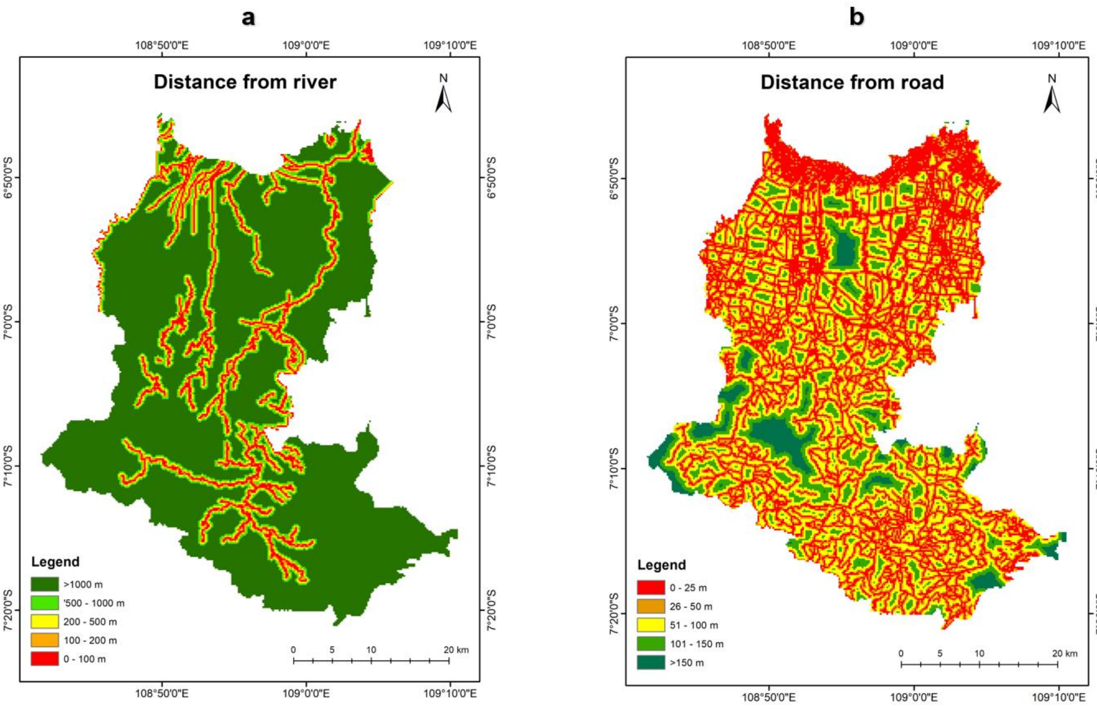

Figure 6. a) Distance from river, b) Distance from road

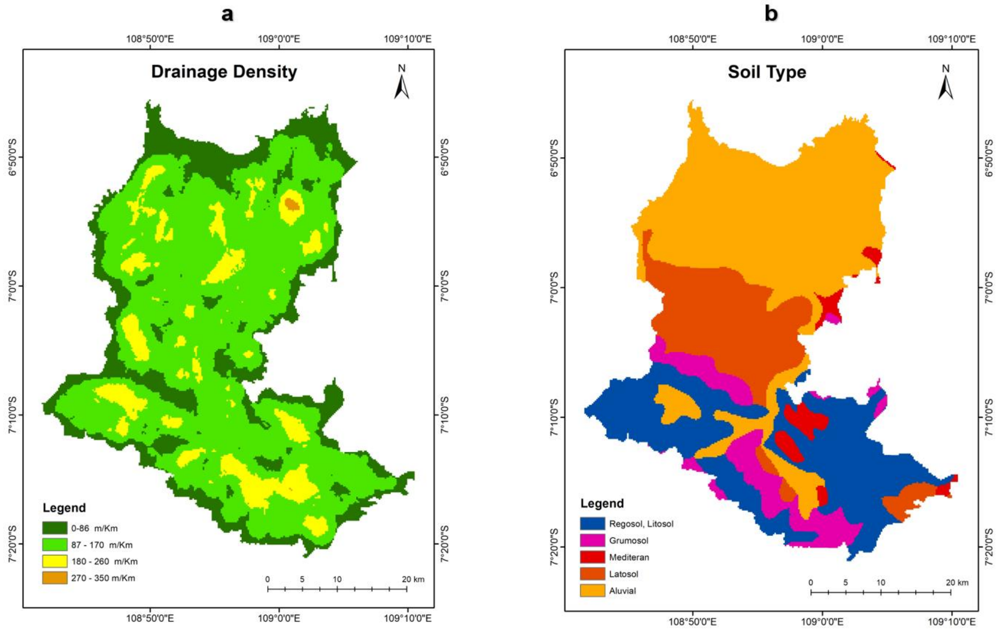

Figure 7. a) Drainage density, b) Soil type

The results of Flood susceptibility mapping of Brebes Region (Figure 8) show that Brebes Regency has a high flood susceptibility is 3.3%, moderate flood susceptibility is 46.39%, low flood susceptibility is 50.03%, and very low flood susceptibility is 0.23%.

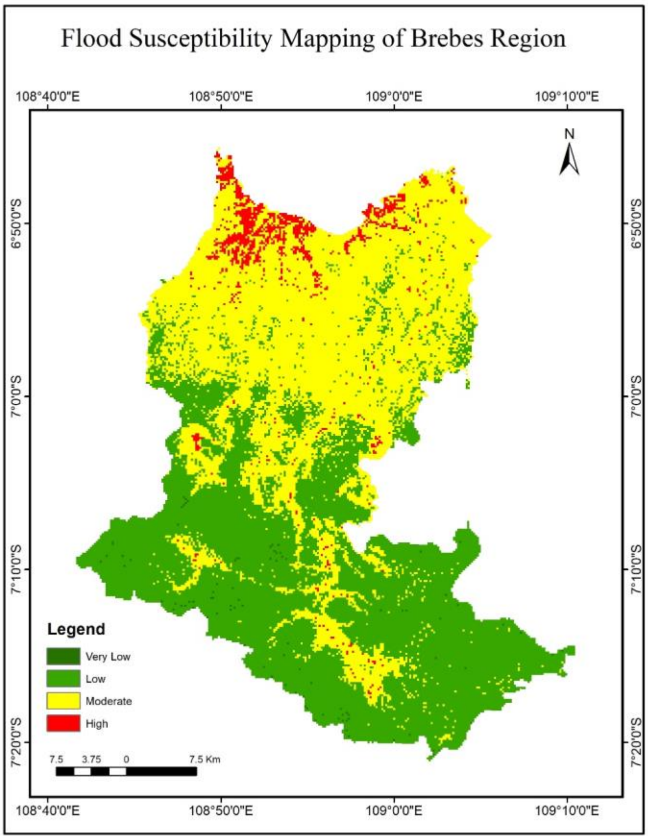

Figure 8. Flood susceptibility mapping of Brebes Region.

Discussion

The distribution of flood vulnerability in Brebes Regency is highly variable, reflecting the complexity of the interplay between geographical characteristics and the impact of human activities on the environment. The high vulnerability in certain areas, particularly in the northern coastal zone, underscores the urgency for developing more resilient infrastructure and effective early warning systems. This research also reveals that the moderate to low flood vulnerability across most of Brebes Regency should not be overlooked, as climate change and weather variability may rapidly alter these conditions. Therefore, plans for flood risk adaptation and mitigation must be dynamic and adaptive, accommodating the possibility of changing future flood risk scenarios. This research further emphasizes the importance of integrating research data into spatial planning and natural resource management to enhance community resilience against flood disasters. In conclusion, this study provides critical insights that can assist stakeholders in making more informed decisions in efforts to reduce flood risk in Brebes Regency.

Conclusions

In conclusion, this research reveals a heterogeneous pattern of flood susceptibility across Brebes Regency, with a spectrum ranging from high to very low vulnerability in specific locales. The application of the Analytic Hierarchy Process (AHP) has proven instrumental in synthesizing various geospatial indicators to evaluate these risks effectively. This approach has enabled the identification of critical areas that warrant prioritized intervention.

Conflict of Interest: The authors declare that there are no conflicts of interest concerning the publication of this article.

References

Journal:

Jamilah Z, Widodo A, Purwanto MS. 2021. Analysis of flood hazards in Magetan Regency using distance sensing method. Journal of Marine-Earth Science Technology

Karra, Kontgis, et al. 2021. Global land use/land cover with Sentinel-2 and deep learning. In Proceedings of the 2021 IEEE International Geoscience and Remote Sensing Symposium (IGARSS). IEEE.

Matondang JP. 2013. Analisis Zonasi Daerah Rentan Banjir Dengan Pemanfaatan Sistem Informasi Geografis (SIG) (Studi Kasus: Kota Kendal dan Sekitarnya). Jurnal Geodesi Universitas Diponegoro. 2(2): 2337-845X.

NASA Shuttle Radar Topography Mission (SRTM)(2013). Shuttle Radar Topography Mission (SRTM) Global. Distributed by OpenTopography. https://doi.org/10.5069/G9445JDF. Accessed: 2023-11-04

Pandulu GD. 2016. Analisis dan pemetaan daerah kritis rawan bencana wilayah UPTD SDA Turen Kabupaten Malang. Jurnal Reka Buana 1(2)

Saaty, T.L. 1980. The Analytical Hierarchy Process: Planning, Priority Setting, Resource Allocation. McGraw-Hill, New York.

Sutikno H, Dewi RS, Saputra A. 2021. Dampak Perubahan Iklim Terhadap Frekuensi Banjir di Kabupaten Brebes. Jurnal Sains dan Teknologi Lingkungan. 13(1): 12-23.

Tarkono, Humam A, Baladiah DSP, Hermastuti GA, Rahmayani I, Mahyunis RV, Sayuti SF. 2021. Pemetaan daerah potensi rawan banjir dengan sistem informasi geografi metode weighted overlay di Kelurahan Keteguhan. Jurnal Geodesi Undip 1(3): 9-152.

Widodo S, Prasetyo LB, Sulistyowati L. 2019. Pengaruh Perubahan Penggunaan Lahan terhadap Risiko Banjir di Kabupaten Brebes. Jurnal Planologi. 16(2): 145-156.

Wirayudha IKA Kusuma, Nuarsa IW, Putra IDN Nurweda. 2020. Pemetaan potensi kerawanan banjir Rob di Kabupaten Gianyar. Journal of Marine Research and Technology 3(2): 94-101. ISSN: 2621-0096 (electronic); 2621-0088

THIS PAGE INTENTIONALLY LEFT BLANK