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ISSN:2302-8149
e-ISSN:2540-9719

Mapping of Flood and Landslide Prone Areas Using Composite Mapping Analysis Method Based on Geographic Information System in East Aceh

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(***received***: ?, ***revised***: ?, ***accepted***: ? diisi oleh editor)

Abstract

Disaster is an event that causes great losses to the community. Disasters are destructive, very detrimental, and require a long time to recover. To overcome the impact of natural disasters on the community in East Aceh Regency, research is needed related to the mapping system for multi-disaster prone areas (floods and landslides) in East Aceh Regency. The application used for the mapping process is ArcGIS Desktop and the research methodology used for mapping is Composite Mapping Analysis which consists of the process of determining the class of each parameter, determining the weight of each parameter by combining each parameter. The method of combining them consists of a scoring process for each parameter, then overlaying the parameters used, calculating and producing relative weights or spatial means, and combining spatial means to produce a value from the weight of each parameter for floods and landslides. The results of the study showed that the percentage of area for the class very prone to flood disasters was 232,156.13 Ha (42.3%), the vulnerable class had an area of 228,634.01 Ha (41.7%), and the non-vulnerable class had an area of 87,687.40 Ha (16%). The percentage of area for the class that is very vulnerable to landslides is 49,998.13 Ha (9.5%), the vulnerable class has an area of 301,863.93 Ha (57.2%), and the non-vulnerable class has an area of 175,542.56 Ha (33.3%). The contribution of this research is to provide information on disaster-prone areas, causal factors, characteristics of vulnerability to natural disasters such as floods and landslides and provide a basis for more effective decision-making in disaster mitigation and management efforts. This approach offers a new contribution to the technology of mapping and classifying disaster-prone areas.

Keywords: Flood and Landslide Disasters, Composite Mapping Analysis, ArcGIS, Mapping System, GIS.

1 Introduction

Natural disasters such as floods and landslides are a serious threat to human survival and the environment and can cause great losses to society [1] [2]. The impacts are environmental damage, economic losses, loss of life and psychological impacts [3]. In Indonesia, floods and landslides are two types of natural disasters that often occur and have quite a big impact. East Aceh Regency, Aceh Province, Indonesia often experiences several natural disasters including floods, landslides and droughts. Based on data from the Central Statistics Agency (BPS) throughout 2023, there were 348 natural disasters, including floods that occurred 35 times, landslides 12 times, and forest and land fires 113 times. Floods and landslides are natural disasters caused by various factors, such as nature and humans [4] [5].

One of the factors that can affect flooding is the intensity, distribution, frequency, and duration of rain. Climate change has an impact on changes in temperature, rainfall, and evapotranspiration, causing changes in the hydrological cycle, lowering of lake water levels, and affecting the availability of watershed water [6]. The physical characteristics of a watershed that can cause flooding are the

ISSN:2302-8149
e-ISSN:2540-9719

watershed area, land slope, elevation, groundwater content, and soil features [7]. Relatively flat areas and large watersheds are one of the factors that cause flooding [8] [9] [10].

Landslides are a form of erosion that causes the transport and movement of large amounts of soil in a short time. They are a common geological disaster throughout the world that causes economic losses and loss of life every year [11] [12] [13] [14] [15]. Landslides are the most destructive natural disasters [16] [17] and have fatal impacts if they affect infrastructure and residential areas [18]. The lack of spatial information can increase the impact and damage caused by disasters in the future, so one way to identify areas prone to flooding and landslides in East Aceh Regency is to conduct a Geographic Information System study and use the Composite Mapping Analysis method [19] [20].

One of the important steps in natural disaster management is mapping and a good understanding of the distribution patterns, vulnerability and resilience to the disaster. Through mapping, we can identify areas that are vulnerable to various types of natural disasters, such as floods, landslides, earthquakes, and to improve flood disaster mitigation and management [21]. This mapping is the basis for decision making in determining the allocation of resources and appropriate mitigation strategies. One approach that can be used to overcome this challenge is to conduct natural disaster mapping using the Composite Mapping Analysis method [22], with the Geographic Information System approach. Geographic Information System is a system used to process and store data and display geographically relevant information [23].

This study aims to identify the spatial distribution of areas prone to flooding and landslides in East Aceh Regency and to become a reference for increasing community preparedness and can be used as a basic reference in carrying out preventive efforts by the East Aceh Regency Government against areas indicated as disasters. This study is also useful for the community to know about disaster-prone areas so that the community can take preventive measures against the risks around them.

This research is important to provide an understanding of natural disaster patterns, causal factors and characteristics of vulnerability and resilience to natural disasters and provide a basis for more effective decision-making in disaster mitigation and management efforts. This research can also be a reference for further research in the field of mapping and clustering of natural disasters.

2 Literature Review

Shariffuddin &Wani, [24] This study produces a landslide disaster vulnerability map in the Gunung Kidul area, Special Region of Yogyakarta. The parameters used are lithology, slope gradient, aspect, vegetation, land use and drainage density. The method used is the Weightage Overlay Method (WOM). The results of this study indicate that the vulnerability map is classified into three zones, namely the low zone, the medium zone and the high zone. The triggering factors for landslides identified are the intensity of heavy rain and earthquakes.

Amen et al, [25] This study aims to identify areas vulnerable to flooding in the central district of Duhok, Iraq using the analytical hierarchy process technique with 12 parameter weights including elevation, slope, distance from rivers, rainfall, land cover, soil lithology, topographic roughness index, topographic wetness index, aspect, sediment transport index and flow strength index to calculate the Flood Hazard Index. The results of this study indicate that 44.72 km2 of the total study area in Duhok City has a very high level of vulnerability to flooding, and these areas require significant attention from the government to reduce flood vulnerability.

Alwi et al, [26] This study aims to identify spatial distribution points that are vulnerable to natural disasters such as landslides, droughts and floods in Semarang Regency. The method used for natural disaster mapping is Spatial Multi-Criteria Evaluation (SMCE). The final results of this study indicate that in Semarang Regency, the dominant area has a fairly high level of vulnerability, followed sequentially by the safe class and then the vulnerable class. It is concluded that structural mountains have a category of fairly high-risk areas and other areas are included in the vulnerable category, while the foot slopes are the areas categorized as the safest.

Chrisnanto et al, [19] GIS-based ranking and categorization of potential impact on drought as disaster mitigation effort in West Bandung Regency (KBB) using Simple Additive Weighting (SAW). This study aims to predict which areas in KBB will be affected by drought by utilizing Geographic Information System (GIS) and Simple Additive Weighting (SAW) method then the parameters used are rainfall density, drought impact, amount of water resources, area per settlement (village), number of

ISSN:2302-8149
e-ISSN:2540-9719

rivers, and number of lakes. The results of this study indicate that there are 162 villages in West Bandung Regency which produce 10 villages with very high drought potential, 30 villages with high potential, 102 villages with average potential, and 20 villages with low drought potential.

Ighile et al, [27] Application of GIS and Machine Learning to Predict Flood Areas in Nigeria. The purpose of this study is to predict flood-prone areas in a much wider coverage area. This study uses artificial neural network (ANN) and logistic regression (LR) methods. Using 15 parameters, namely elevation, TWI, SPI, roughness, slope, soil information, distance to water, roads, railways, rainfall, temperature, curvature, and land use, aspect ratio and curve number. The results of this study indicate that areas with high flood vulnerability are mainly dominant in areas with extensive human activity, such as agricultural land and settlement areas. Likewise, due to the large number of human activities in Nigeria, the likelihood of flooding in this study may change over time.

From several previous related studies that have been conducted by other researchers, there are differences with the research conducted by this researcher. The differences can be seen in the types of disasters studied, the area of analysis, the number of parameters and methods used, and the implementation of the analysis results maps.

In addition to this research, there are several studies that have been conducted by researchers related to this and the implementation of the mapping application system, including research on data mining approach for rainfall analysis using multiple linear regression method (case study: North Aceh District) [28], the implementation of fuzzy c-means to determine the level of student satisfaction in online learning [29], application of the profile matching analysis method to the decision support system for study program recommendations [30] and application for mapping the location of 3 kg lpg gas distribution using the android-based ant colony algorithm [31].

3 Research method

East Aceh Regency is located between 4˚09'21.08" - 5˚06'02,16" North latitude and 97˚15'22.07" - 97˚34'47.22" East Longitude, with altitudes varying from 0 to 240 meters above sea level and slopes between 1-5˚. The region has a tropical climate that is influenced by the monsoons: the dry season from June to December and the rainy season from September to March, as well as a transitional season that connects the two seasons. The average temperature ranges from 26°-30°C. The highest rainfall in 2023 occurred in January, with 19 rainy days and rainfall reaching 488 mm^3 (BPS, 2023). East Aceh District has an area of 6,040.60 km^2, which is 10.53 percent of the area of Aceh Province, and is administratively divided into 24 sub-districts, 59 residence, and 513 villages. Based on its topography, the region has 4 slope classes: 0-2%, 2-15%, 5-40%, and >40%, with slopes >40% covering only 6.7% of the total area, covering Serbajadi and Birem Bayeun sub-districts, while the rest of the region has an average slope between 0-40%.

3.1 Research Methods or Stages

The methods or stages carried out in this research are as follows:

1. The first stage of data collection is in the form of geographic data (spatial data) and hydrological data. Spatial data includes DEM SRTM (Digital Elevation Model Shuttle Radar Topography Mission) data with a resolution of 30 meters and Indonesian Topographic Map data. Hydrological data includes rainfall data, river basin data, temperature data and flood and landslide incident data in East Aceh Regency.
2. Surveys and observations are carried out for direct observation in the field and support the process of summarizing information in the field as a reference for research.
3. Data validation to ensure that the data previously described in point 1 meets the criteria and the source and truth of the data can be explained.
4. Data processing for flood hazard maps has several processes, namely plotting rainfall points, cropping, calculating the area of the River Basin Area, calculating flow density, interpolating rainfall points, slope, reclassifying and editing attributes. Data processing for landslide hazard maps includes plotting rainfall points, cropping, scoring, reclassifying, editing attributes and overlay.
5. Making a flood model in the form of a rainfall map which is the result of plotting and interpolation, a land slope map and an elevation map which are the results of slope and reclassify, and a flow density map which is the result of calculating the area of the River Basin Area and calculating flow

ISSN:2302-8149
e-ISSN:2540-9719

density. Furthermore, a scoring process is carried out then an overlay which can produce a flood hazard map.
6. Making a landslide model in the form of a rainfall map, soil type map, land slope map and land use map are the results of slope and reclassify then scoring and overlay will be carried out to produce a landslide hazard map.
7. Next is the creation of Web GIS. At this stage, an analysis is carried out for the needs of Web GIS, Web GIS design, then Web GIS implementation.
8. The last stage is the presentation of results and analysis. The analysis is carried out for system testing and validity testing that has been made previously.

3.2 Research Data Used

The data used for analysis in this study are:
1. Population data
2. Indonesian Topographic Map (RBI) data
3. SRTM DEM map data with 30-meter resolution
4. Rainfall data in 2023
5. BMKG temperature data in 2023
6. River basin (DAS) data in East Aceh Regency
7. Flood and landslide incident data in East Aceh Regency in 2018-2023
8. Soil type data from the Ministry of Energy and Mineral Resources 2018
9. Land use data from the Ministry of Environment and Forestry 2020

4 Results and Discussion

The map of East Aceh Regency depicts various geographical aspects that are relevant for disaster risk analysis such as floods and landslides. The parameters used as causes of flooding and landslides are: rainfall parameters, land slope, soil type, land use, height and flow density.

4.1 Flood and Landslide Disaster Parameter Layout Map

The rainfall map shows the distribution of average daily rainfall during 2023 with blue shading indicating rainfall intensity. Black dot symbols mark the locations of rainfall stations, while red lines indicate arterial and local road networks, and blue lines represent rivers in the area (Figure 1). The land slope map illustrates the level of slope with green for low slopes (0-8%) which have a low risk of landslides, and red for high slopes (more than 45%) which have a high risk of landslides. The map also shows the road and river networks, as well as administrative boundaries of sub-districts and between sub-districts in Figure 2.

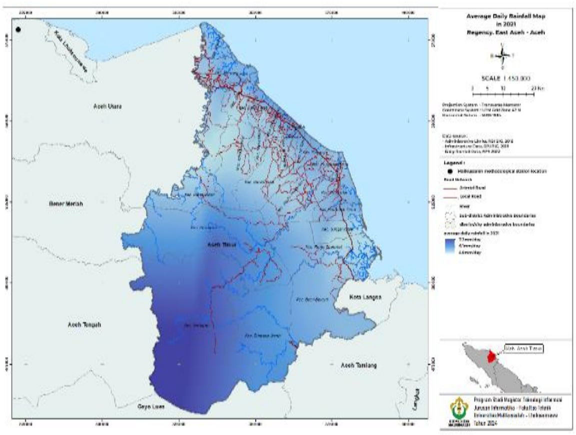

Figure 1. Rainfall map.

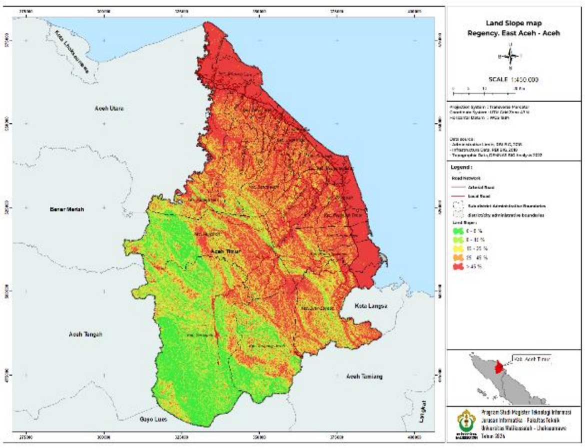

Figure 2. Land Slope Map

The soil type map shows the dominance of sedimentary soil types (dark blue color) which tend to have low density and are prone to landslides. In coastal areas, the dark purple color indicates the dominance of alluvium soil types that are also vulnerable to the impact of human activities and high rainfall (Figure 3).

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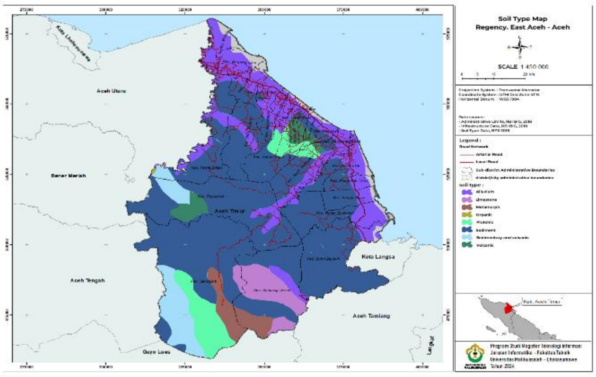

Figure 3. Soil Type Map

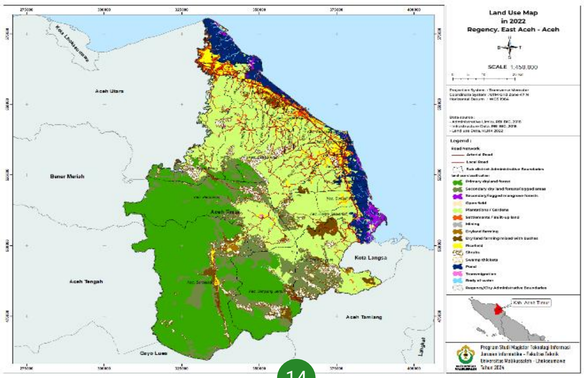

Figure 4. Land Use Map

The land use map shows land use for plantations and community gardens (light green color) and primary dryland forest (dark green color). This provides an overview of the potential impact of human activities on disaster risks such as fire and landslides (Figure 4).

The shading symbol of the area that has a color in the legend shows that starting from the red color which has a land height value of more than 100 m, it is an area with a high land height but has the lowest flood risk in its class and moving towards the green color which has a land height value of less than 25 m, which shows that the percentage of land height is getting lower but the risk of flooding will be higher (Figure 5).

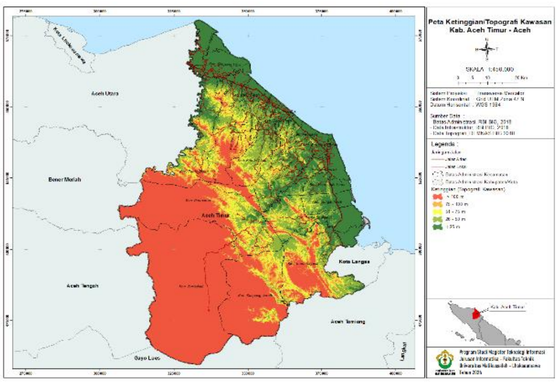

Figure 5. Height Map

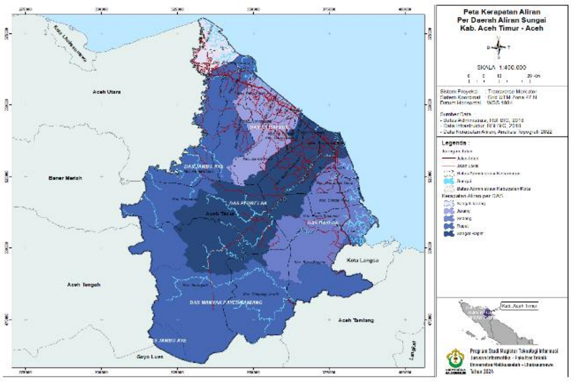

Figure 6. Flow Density Map

The flow density map is the result of processing DAS (river basin) data and DEM SRTM analysis of East Aceh Regency. The shading symbol of the flow density area per river basin that has a color in the legend shows that starting from the light blue color which has a very rare density value has the highest risk of vulnerability in its class, and the darker the blue color indicates that the area has a very dense flow density value, where the area has a lower risk of vulnerability (Figure 6).

4.2 Determination of Flood and Landslide Parameter Weights

The process of calculating the weight of the six flood and landslide vulnerability analysis parameters begins by overlaying rainfall data, land slope, land use, soil type, altitude and flow density using ArcGIS software. The results of the overlay are in the form of flood and landslide vulnerability maps showing zones with different levels of vulnerability as in Figure 7 and Figure 8. Furthermore, the flood vulnerability map resulting from the overlay with flood event data from 2018-2023 produces a flood-prone area map as in Figure 9. Overlay between the landslide event map and the landslide vulnerability map is carried out to produce a landslide-prone area map in Figure 10. The final stage is to calculate the spatial average of each parameter to determine the relative weight of each potential cause of flooding and landslides in East Aceh Regency.

The next step is to calculate the spatial average of each parameter to obtain the weight of each cause of flooding and landslides. The results of the spatial average calculation are then used to calculate the weight of all parameters causing flooding and landslides by using equation 1.

 ISSN:2302-8149
e-ISSN:2540-9719

$$Weight = \frac{100}{Total\ Mean\ Spatial} \times Mean\ Spatial\ (Variabel) \quad (1)$$

To obtain flood and landslide vulnerability scores, group them into 3 vulnerability classes, namely very vulnerable, vulnerable and not vulnerable, by using equation 2:

$$c = w_1x_1 + w_2x_2 + w_nx_n \quad (2)$$

Where:

C = Floods and Landslide occurrence
w_I = Weight of Floods and landslide occurrence parameter
x_I = Criterion score of parameter causing a Floods and landslide
i dan n = Number of parameters

The results of the analysis on the flood-prone area map in East Aceh Regency are divided into 3 classes, namely very vulnerable, vulnerable, and not vulnerable. Sub-districts that are included in the very vulnerable class include: Darul Falah District, Nurussalam District, Pante Bidari District, Ranto Peureulak District, Julok District, Banda Alam District, Peudawa District, Peureulak District, Sungai Raya District, East Peureulak District, Idi Rayeuk District, Idi Tunong District, Simpang Ulim District, Indra Makmur District, Darul Aman District, Birem Bayeun District, West Peureulak District, Darul Ihsan District, Madat District, and Rantau Selamat District. Sub-districts that are included in the vulnerable class include: Simpang Jernih District, Peunaron District, and East Idi District. Meanwhile, the only sub-district that is included in the non-vulnerable class is Serba Jadi Sub-district.

The result of the analysis of the landslide prone area map in East Aceh District shows the division into three vulnerability classes: not vulnerable, vulnerable and highly vulnerable. None of the sub-districts are included in the highly vulnerable class. Sub-districts that fall into the vulnerable class include Birem Bayeun, Indra Makmur, Pante Bidari, Peunaron, Serbajadi, and Simpang. Meanwhile, the other 18 sub-districts are classified as not prone to landslides.

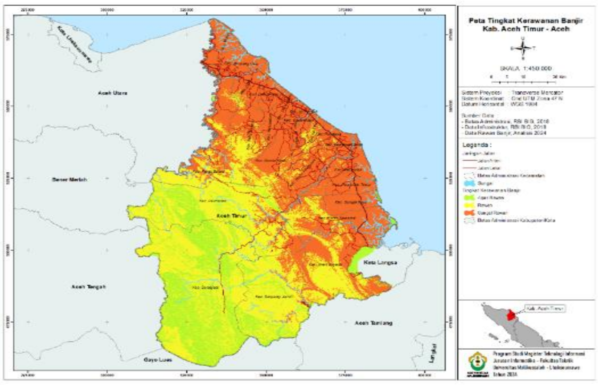

Figure 7. Flood Vulnerability Map

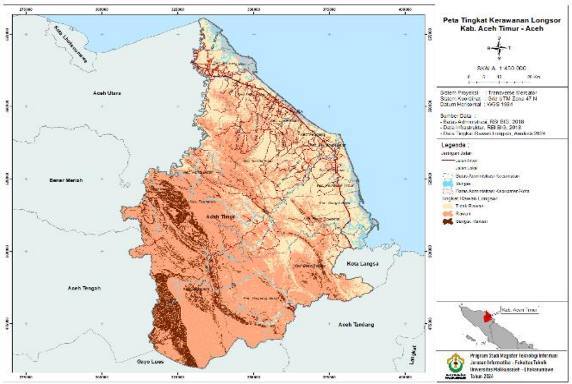

Figure 8. Landslide Susceptibility Map

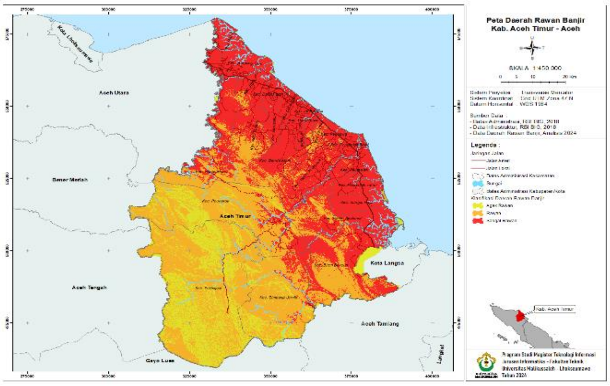

Figure 9. Map of Flood Prone Areas in East Aceh Regency

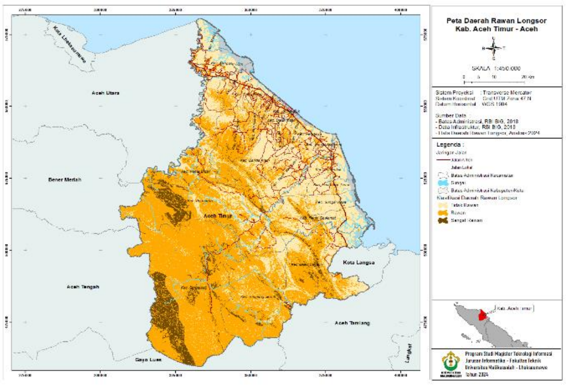

Figure 10. Map of Landslide Prone Areas in East Aceh Regency

4.2.1 Results of Flood Disaster Parameter Calculations

After the overlay process of the flood event map and the flood vulnerability map to produce a flood-prone area map, the next stage to obtain the parameter weight of each flood-causing parameter is

ISSN:2302-8149
e-ISSN:2540-9719

to calculate the spatial mean of the 4 flood-causing parameters. The following is the calculation of the spatial mean of each parameter in Table 1, Table 2, Table 3, and Table 4.

Table 1. Calculation of Spatial Mean of Rainfall Parameters

Average Daily Rainfall (mm)	Area (Ha)	Flood Prone (Ha)	Flood Prone Ratio	Flood Prone Area Ratio
<20	540.246,94	460.372,04	0,85	1,00
21-40	-	-		
41-75	-	-		
75-150	-	-		
>150	-	-		
Total	540.246,94	460.372,04	*Mean Spatial*	0,85

Table 2. Calculation of Spatial Mean from Land Slope Parameters

Land Slope	Area (Ha)	Flood Prone (Ha)	Flood Prone Ratio	Flood Prone Area Ratio
>45%	66.968,97	877,30	0,01	0,00
26-45%	82.903,16	68.387,45	0,82	0,15
16-25%	80.866,47	81.110,63	1,00	0,18
8-15%	112.366,38	112.610,56	1,00	0,24
0-8%	197.141,96	197.386,11	1,00	0,43
Total	540.246,94	460.372,04	*Mean Spatial*	0,97

Table 3. Calculation of Spatial Mean From Height Parameters

Height (m)	Area (Ha)	Flood Prone (Ha)	Flood Prone Ratio	Flood Prone Area Ratio
>100	248.609,88	167.332,95	0,67	0,36
75-100	38.198,69	38.508,76	1,01	0,08
51-75	60.203,14	60.592,68	1,01	0,13
26-50	80.593,31	80.976,64	1,00	0,18
<26	112.641,92	112.961	1,00	0,25
Total	540.246,94	460372,04	*Mean Spatial*	0,88

Table 4. Calculation of Spatial Mean From Flow Density Parameters

Watershed Flow Density	Area (Ha)	Flood Prone (Ha)	Flood Prone Ratio	Flood Prone Area Ratio
Sangat Rapat	136.948,26	114.144,35	0,83	0,25
Rapat	261.112,20	203.062,68	0,78	0,44
Sedang	80.275,02	80.257,87	1,00	0,17
Jarang	45.996,17	46.492,95	1,01	0,10
Sangat Jarang	15.915,29	16.414,18	1,03	0,04
Total	540.246,94	460372,04	*Mean Spatial*	0,86

The results of the spatial mean calculation are then used to calculate the weight of all the parameters that cause flooding, using the equation 3.

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e-ISSN:2540-9719

$$Bobot = \frac{100}{Overall\ Mean\ Spatial} \times Mean\ Spatial\ (Variables) \quad (3)$$

The following are the results of the weight calculation using the Composite Mapping Analysis method in Table 5.

Table 5. Results of Calculation of Parameter Weights for Flood Causes

No	Flood Parameters	*Mean Spatial*	Weight
1	Rainfall	0,85	23,85
2	Land Slope	0,97	27,25
3	Height	0,88	24,75
4	Flow Density	0,86	24,15

To obtain the flood vulnerability value and classify it into 3 vulnerability classes, namely very vulnerable class, vulnerable class and non-vulnerable class, a calculation process is carried out using the equation 4.

$$C = w_1x_1 + w_2x_2 + w_nx_n \quad (4)$$

Total Score Value of Flood Vulnerability Parameters in Table 6.

Table 6. Total Score Value of Flood Vulnerability Parameters

Class Score (x)	Rainfall (w_1)	Land Slope (w_2)	Height (w_3)	Density (w_4)	Flood Event (w_5)	Total
1	23,85	27,25	24,75	24,15	0	100
2	0	54,5	49,5	48,3	2	154,3
3	0	81,75	74,25	72,45	5	233,45
4	0	109	99	96,6	8	312,6
5	0	136,25	123,75	120,75	12	392,75

After getting the value of the total number of parameter scores, then the value of the x parameter score is added up according to its class score, then the result is added up with the total flood events, resulting in the highest value data and the lowest value data. After getting the highest data value and the lowest data value, do the calculation using the formula *Ki* to get the interval width of the three vulnerability classes used by using the equation 5.

$$Ki = \frac{Xt - Xr}{k} \quad (5)$$

Where,

Ki = Interval Width
Xt = Highest data
Xr = Lowest data
k = Number of intervals

The results of the analysis of the equation above are as follows

$$Ki = \frac{Xt - Xr}{k} = \frac{392{,}75 - 100}{3} = 98$$

The interval width for the 3 vulnerability classes is 98, so the first class or the non-vulnerable vulnerability class has a value range of 100-198 obtained from the sum of 100+98, the second class or vulnerable class has a value range of 198-296, obtained from the sum of 198+98 and the third class or very vulnerable class has a value range of 296-394 obtained from the sum of 296+98.

The results of the analysis on the flood-prone area map in East Aceh Regency are divided into 3 classes, namely very vulnerable, vulnerable, and not vulnerable. Sub-districts included in the very vulnerable class include: Darul Falah District, Nurussalam District, Pante Bidari District, Ranto Peureulak District, Julok District, Banda Alam District, Peudawa District, Peureulak District, Sungai Raya District, East Peureulak District, Idi Rayeuk District, Idi Tunong District, Simpang Ulim District, Indra Makmur District, Darul Aman District, Birem Bayeun District, West Peureulak District, Darul Ihsan District, Madat District, and Rantau Selamat District. Sub-districts included in the vulnerable class include:

ISSN:2302-8149
e-ISSN:2540-9719

Simpang Jernih District, Peunaron District, and East Idi District. Meanwhile, the sub-districts that are included in the non-prone class are only Serba Jadi Sub-districts. The following is the percentage of flood-prone areas in East Aceh Regency in Table 7.

Table 7. Total Area of Flood-Prone Areas in East Aceh Regency

Vulnerability Class Classification	Area of the Region (Ha)	Percentage
Not vulnerable	87.687,40	16%
Vulnerable	228.634,01	41,7%
Very Vulnerable	232.156,13	42,3%

4.2.2 Landslide Disaster Parameter Calculation Results

The overlay process of landslide occurrence maps and landslide susceptibility maps produces a map of landslide-prone areas, the next stage to obtain the parameter weights of each landslide-causing parameter is to calculate the spatial mean of the 5 landslide-causing parameters. The following are the results of calculating the spatial mean of each landslide-causing parameter in Table 8, Table 9, Table 10, Table 11 and Table 12.

Table 8. Calculation of Spatial Mean of Rainfall Parameters

Average Daily Rainfall (mm)	Area (Ha)	Landslide Prone (Ha)	Landslide Prone	Ratio Landslide Prone Area
<20	542.418,86	333.871,49	0,62	1,00
21-40	-	-	-	-
41-75	-	-	-	-
75-150	-	-	-	-
>150	-	-	-	-
Total	542.418,86	333.871,49	Mean Spatial	0,62

Table 9. Spatial Mean Calculation of Land Slope Parameters

Land Slope	Area (Ha)	Landslide Prone (Ha)	Landslide Prone Ratio	Landslide Prone Area Ratio
>45%	66.968,97	66.907,91	1,00	0,20
26-45%	82.903,16	82.681,31	1,00	0,25
16-25%	80.866,47	77.735,24	0,96	0,23
8-15%	112.366,38	73.002,17	0,65	0,22
0-8%	197.141,96	33.544,86	0,17	0,10
Total	540.246,94	333.871,49	Mean Spatial	0,83

Table 10. Calculation of Spatial Mean of Land Use Parameters

Land Use	Area (Ha)	Landslide Prone (Ha)	Landslide Prone Ratio	Landslide Prone Area Ratio

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Protection Forest and Forest Primary	215.285,31	159.938,83	0,74	0,48
Secondary Forest	63.951,54	54.857,55	0,86	0,16
Plantation	226.840,11	101.004,54	0,45	0,30
Rice fields, moorland, shrubs	19.201,92	3.316,05	0,17	0,01
Open Land and Settlement	17.367,79	14.754,52	0,85	0,04
Total	540.246,94	460.372,04	Mean Spatial	0,86

Table 11. Spatial Mean Calculation of Soil Type Parameters

Soil Type	Area (Ha)	Landslide Prone (Ha)	Landslide Prone Ratio	Landslide Prone Area Ratio
Organic	182,03	15,77	0,09	0,00
Plutonic	31.820,79	20.505,77	0,64	0,06
Limestone and Metamorphic	42.379,38	36.924,71	0,87	0,11
Sediments	330.636,46	220.837,41	0,67	0,66
Alluvium and Volcanics	124.726,95	55.817,03	0,45	0,17
Total	542.336,81	333.871,49	Mean Spatial	0,83

Table 12. Calculation of Spatial Mean of Altitude Parameters

Elevation (m)	Area (Ha)	Landslide Prone (Ha)	Landslide Prone Ratio	Landslide Prone Area Ratio
>100	249.049,03	235.189,26	0,94	0,70
75-100	38.600,68	33.112,46	0,86	0,10
51-75	60.619,58	36.633,22	0,60	0,11
26-50	81.013,38	16.426,88	0,20	0,05
<26	113.054,13	12.509,67	0,11	0,04
Total	542.336,81	333.871,49	Mean Spatial	0,83

Table 13. Results of The Calculation of The Weight of The Meters Causing Landslides Using Composite Mapping Analysis Method

No	Flood Parameter	*Mean Spatial*	Weight
1	Rainfall	0,62	17,10
2	Land Slope	0,83	23,06
3	Land Use	0,67	18,63

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4	Soil Type	0,65	18,13
5	Elevation	0,83	23,08

Table 14. Total Score Of Landslide Susceptibility Parameter Values

Score (x)	Rainfall (w_1)	Land Slope (w_2)	Elevation (w_3)	Land Use (w_4)	Land Type Soil (w5)	Landslide Event (w6)	Total
1	17,1	23,06	23,08	18,63	18,13	1	101
2	0	46,12	46,16	37,26	36,26	2	167,8
3	0	69,18	69,24	55,89	54,39	4	252,7
4	0	92,24	92,32	74,52	72,52	0	331,6
5	0	115,3	115,4	93,15	90,65	0	414,5

After getting the total number of parameter scores, the value of the x parameter scores is added according to the class score. The results are added to the total flood incidence, resulting in the highest and lowest-value data. After getting the highest and lowest data values, calculate using the Ki formula to get the interval width of the three vulnerability classes used; using the equation 6.

$$Ki = \frac{Xt - Xr}{K} \quad (6)$$

The sub-Regency included in the non-prone class is the Serba Jadi sub-Regency. The sub-Regency included in the non-prone class is the Serba Jadi sub-Regency. The results of the analysis of the landslide-prone area map in East Aceh District show a division into three vulnerability classes: not prone, prone, and very prone. No sub-district belongs to the very prone class. Sub-districts in the vulnerable class include Birem Bayeun, Indra Makmur, Pante Bidari, Peunaron, Serbajadi, and Simpang. Meanwhile, the other 18 sub-districts are classified as not prone to landslides in Table 15.

Table 15. Total Area Prone to Landslides in East Aceh District

Classification of Vulnerability Class	Area (Ha)	Percentage
Not vulnerable	175.542,56	33,3%
Prone	301.863,93	57,2%
Very vulnerable	49.998,13	9,5%

4.3 Display of the Disaster Prone Area Identification Page

The disaster-prone area identification page shows sub-districts that have a certain level of vulnerability in East Aceh Regency. On the page display, the sub-districts that are identified as areas that are very vulnerable to flooding are areas that have red shading. The sub-districts that are included in the areas that are very vulnerable to flooding are Darul Falah Sub-district, Nurussalam Sub-district, Pante Bidari Sub-district, Ranto Peureulak Sub-district, Julok Sub-district, Banda Alam Sub-district, Peudawa Sub-district, Peureulak Sub-district, Sungai Raya Sub-district, East Peureulak Sub-district, Idi Rayeuk Sub-district, Idi Tunong Sub-district, Simpang Ulim Sub-district, Indra Makmur Sub-district, Darul Aman Sub-district, Birem Bayeun Sub-district, West Peureulak Sub-district, Darul Ihsan Sub-district, Madat Sub-district, and Rantau Selamat Sub-district . Identification map of areas that are highly vulnerable to flooding in Figure 11.

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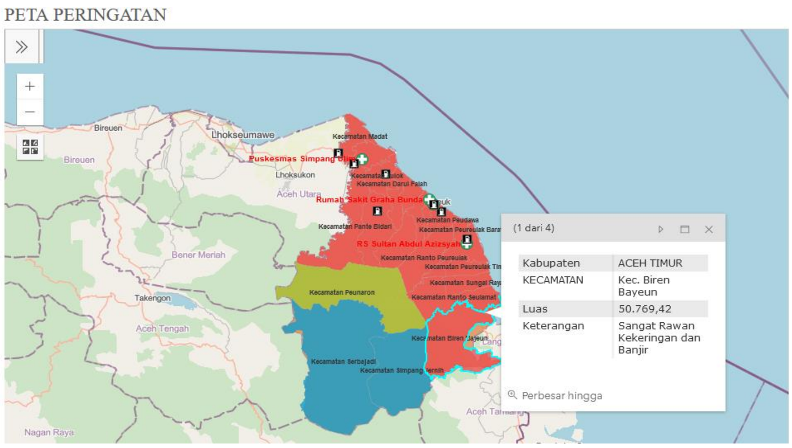

Figure 11. Identification of Highly Flood Prone Areas

Areas that have blue shading are areas that are prone to landslides. Landslide-prone areas are Simpang Jernih District, Serbajadi District, Peunaron District. Landslide-prone Area Identification Map in Figure 12.

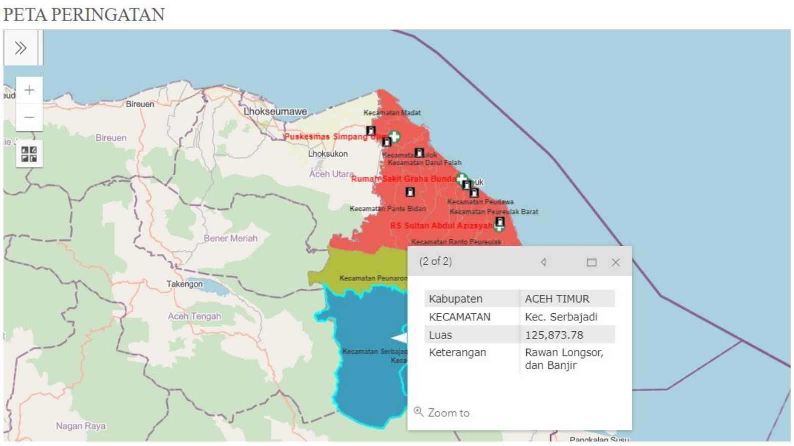

Figure 12. Identification of Landslide Prone Areas

4.4 Disaster Vulnerability Level Analysis Results

The following are the results of the analysis of the vulnerability map for each disaster in the form of the percentage of area vulnerability to a disaster. Results of the percentage level of landslide susceptibility for each sub-district in Figure 13.

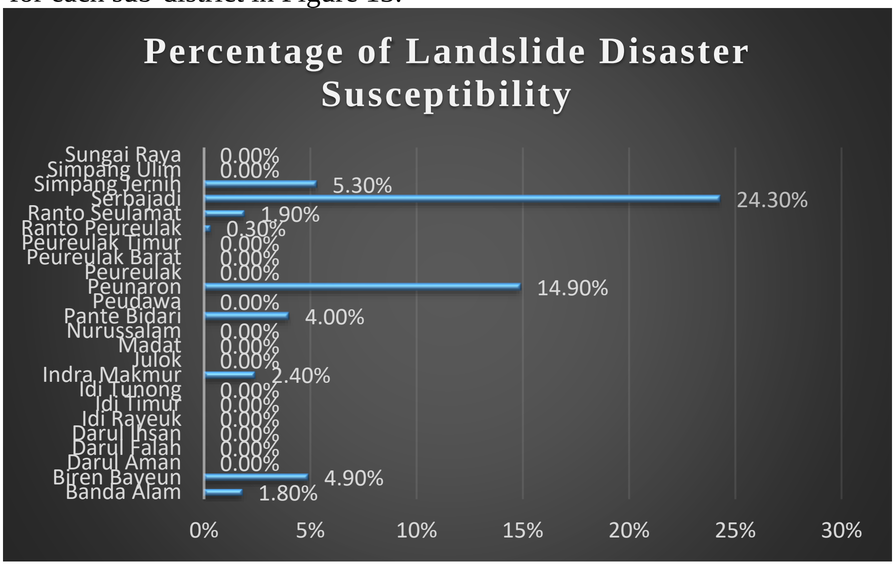

Figure 13. Percentage of Landslide Disaster Susceptibility

ISSN:2302-8149
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Based on Figure 14, it can be concluded that the majority of sub-districts in the East Aceh Regency area are sub-districts that are not prone to landslides. The data visualized is the percentage of the highest level of vulnerability. This can happen because most of the areas in East Aceh Regency are lowland. Furthermore, for flood disasters, it can be seen in Figure 14 that most areas in East Aceh Regency are areas that are very prone to flooding. The following data is visualized in the graph below. The visualized data is the percentage of the highest level of vulnerability and East Aceh Regency has a very high percentage of vulnerability to flood disasters.

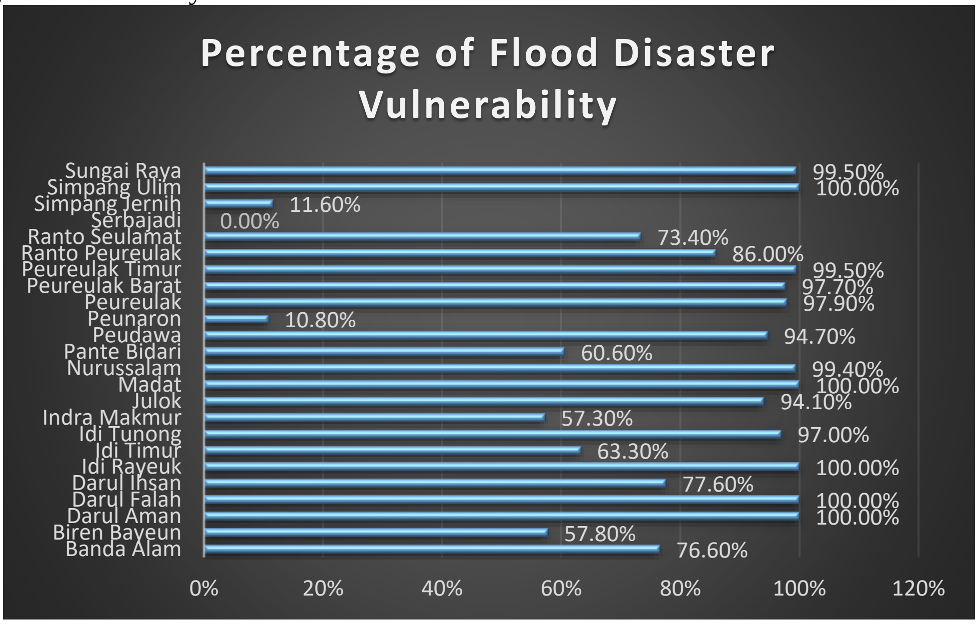

Figure 14. Percentage of Flood Disaster Vulnerability

5 Conclusion

The results of the mathematical weight calculation for each parameter used as a reference for flood-prone areas are rainfall, land slope, land height, and flow density. The results of the mathematical weight calculation of each parameter, the rainfall weight is 23.85, the land slope parameter is 27.25, the land height parameter is 24.75 and the flow density parameter weight is 24.15. The parameters used as a reference for landslide-prone areas are rainfall, land slope, land height, land use and soil type. The results of the mathematical weight calculation of each parameter, the rainfall weight is 17.10, the land slope parameter is 23.06, the land height parameter is 23.08, the land use parameter weight is 18.63 and the soil type parameter weight is 18.13. The processing of flood-prone area maps in East Aceh Regency using the Composite Mapping Analysis method obtained the results of the area of flood-prone areas which have been divided into 3 classes, namely the very vulnerable class has an area of 232,156.13 Ha (42.3%), the vulnerable class has an area of 228,634.01 Ha (41.7%) and the non-vulnerable class has an area of 87,687.40 Ha (16%). While the processing of landslide-prone area maps in East Aceh Regency using the Composite Mapping Analysis method obtained the results of the area of landslide-prone areas which have been divided into 3 classes, namely the very vulnerable class has an area of 49,998.13 Ha (9.5%), the vulnerable class has an area of 301,863.93 Ha (57.2%) and the non-vulnerable class has an area of 175,542.56 Ha (33.3%). Processing maps of flood and landslide prone areas using the Composite Mapping Analysis method has succeeded in dividing areas into vulnerability classes, so that areas that are very vulnerable, vulnerable, and not vulnerable to floods and landslides can be seen.

Acknowledgments

We acknowledge the support grant and research funding received from The the Directorate of Research, Technology, and Community Service. Ministry of Education, Culture, Research and Technology in 2024, grant number: 242/UN45.3.1/AL.04/VI/2024.

ISSN:2302-8149
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