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AHP Scoring and Weighting Main Criteria For Assessment of Potential Hydrometeorological Disasters: A Literature Study

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Abstract

In general, the territory of Indonesia is prone to hydrometeorological disaster events. In disaster management, it is necessary to map the source or level of potential disaster hazards. The Analytic Hierarchy Process (AHP) method has been used to determine the relative importance of each criterion for potential mapping disasters. This literature study aims to determine the criteria and weighting in the AHP approach that can be used in assessing the potential for hydrometeorological disasters. This literature review is limited by analyzing and assessing the potential, vulnerability, and vulnerability of floods, landslides, and tornadoes using the AHP method. The input data used in the literature is based on the opinions of experts, interested stakeholders, and related regulations to determine the criteria and their weighting. The results of this literature review show that the three criteria are the dominant determining factors in assessing and analysing the three hydrometeorological disasters. The scoring of each criterion is based on its impact on the disaster.

Keywords: AHP, hydrometeorological disaster, criteria, weighting

1. Introduction

Natural disasters, especially hydro-meteorological disasters, are a priority for assessing disaster threats mentioned in article 4, paragraph 2 of National Disaster Management Agency (BNPB) Regulation Number 7 of 2022. Hydrometeorological disasters are directly related to the weather and climate on the earth's surface and atmosphere, which impact the disruption of people's lives PVMBG in Hermon (2012). Examples are floods, landslides and strong winds (tornado). This catastrophic event indeed resulted in both losses of life and material. Efforts are needed to organize disaster management at the pre-disaster stage, which can be realized in disaster risk reduction actions (BNPB, 2019). In this effort, several steps or actions must be taken, namely identifying and mapping the sources or levels of potential disaster hazards so that anticipation can be taken against the possibility of a disaster. In the study of determining the level of potential disaster hazard, the Analytic Hierarchy Process (AHP) method is used to determine the relative importance of the criteria as in many decision problems, and it has succeeded in reducing the appropriate weight of each criterion in each hazard mapping (Morales and de Vries, 2021).

In its application, the method from the AHP approach transforms relatively significant subjective judgments into a set of overall scores or weights (Saaty, 2008). According to Dodgson et al. (2009), this method was initially invented and designed by Saaty in 1980. This method is used in decision-making problems that are arranged hierarchically at different levels. The decision-making method using the AHP approach has been used in various fields, including determining the suitability of airport construction sites (Syafi'i et al., 2022), urban planning (Sharma and Miyazaki, 2019; Ulfiana et al., 2021), land suitability (Tashayo et al., 2020), food vulnerability (Hussain et al., 2021), multi-disaster risk assessment (Aksha et al., 2020; Azmiyati and Poernomo, 2019), water resources management (Tarigan et al., 2018). In many studies, combining and comparing two decision-making methods so that the results obtained can be more rational and objective, such as the Fuzzy-AHP method (Abdullah et al., 2021), TOPSIS-AHP (Pishyar et al., 2020; Ulfiana et al., 2021), AHP-Model Maxent (Cabrera and Lee, 2020).

The stages in AHP require opinions from experts in their fields and relevant stakeholders to determine the criteria or variables to be used and determine the weight of these criteria. Therefore, this research aims to determine the criteria and weighting in the AHP approach to assessing the potential for floods, landslides and tornadoes based on literature studies. This weighting is hoped to be used to assess the

potential for disaster hazards, especially in Hamparan Perak District, Deli Serdang Regency.

2. Research Method

This study uses the method of literature review. The scope of this research is to study the assessment of potential, susceptibility, and vulnerability to floods, landslides, and tornadoes using the AHP method based on the opinions of experts and interested stakeholders to determine the criteria and their weighting. The initial stage of this literature review research begins with identifying library sources, collecting literature, and filtering the literature obtained. Then the data obtained will be presented in the form of data tabulations and analyzed, as shown in **Figure 1**.

Identification and data collection were carried out by searching previous research on Google Scholar and Mendeley within ten years. The search keywords used were AHP flood disaster, AHP landslide disaster, and AHP tornado disaster. The collected literature is then filtered according to the desired research reference criteria, namely a hydrometeorological hazard assessment study using the AHP method. Another criterion is to use the opinion of experts, relevant stakeholders, or related regulations as a source of AHP data input.

The next stage is the grouping of libraries based on the results of library screening. The selected literature from the screening stage was grouped based on the type of disaster research being conducted, namely flood, landslide, and tornado assessments. The results of searching information from the grouped literature are then made into tables for analysis. The analysis is carried out mainly on the score or weighting given to each criterion used in the disaster assessment process. The author's point of view as an observer and meteorological forecaster also influences the analysis results from this literature study.

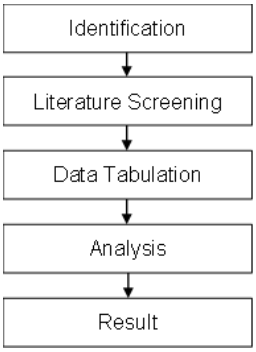

Fig. 1. Research design flowchart

3. Results and Discussion

Taking the weight of the criteria uses some credible literature from several sources. The results of a review of several sources are used as reference material to determine the criteria or research variables for potential disasters. In addition, this study also studied the effect of each research variable on disasters in the Hamparan Perak District, Deli Serdang. Hamparan Perak District, Deli Serdang Regency, has an area of 230.15 km^2, or about 9.21% of the area of Deli Serdang Regency (BPS Kabupaten Deli Serdang, 2022).

Research to assess flood risk in Davao Oriental Philippines by comparing the AHP method with the Maximum Entropy Model (Cabrera and Lee, 2020).

3.1 Flood assessment

Research and studies on flood hazard using the opinion of experts have been widely used, especially in academic studies. Research conducted by Ramadhani et al. (2022) shows that the hydrological aspect significantly influences flooding, giving it a high score. The research used the opinions of experts and stakeholders from Malang City Regional Disaster Management Agency (BPBD) employees, Malang City Regional Development Planning Agency (BAPPEDA) employees, and Malang city Public Works, Spatial Planning, Housing and Settlement Area (DPUPRPKP) employees. The scoring of each parameter depends on its effect on the flood disaster. The higher the score on a variable parameter, the higher the effect, where the rainfall parameter has the most significant influence on flooding, with a weight of 50% compared to the other seven parameters (**Figure 2**).

Research on giving weight to each criterion to assess flood vulnerability as part of urban planning was carried out by Ulfiana et al. (2021) in Klaten Regency and Haris et al. (2022) in Kuningan Regency. The assessment of the weight of the criteria comes from experts in the field of disaster, land or physical resources, and spatial planning, as well as academics and several community leaders in the research area. The weight assessment produces a criterion importance scale. In Klaten District, land use and rainfall are the most important criteria in determining the level of flood vulnerability, while slope and geological conditions are the criteria that are considered the least important compared to other criteria. In Kuningan Regency, the weight of the determining factors with the highest weight is rainfall, relative humidity, and land use. In another study, rainfall and land use were also criteria with the most important and influential scale in assessing flood vulnerability compared to the other three criteria in Subahagio (2021).

Information	Parameter	Weight	Total Weight
Criteria	Physical	40%	100%
	Hydrology	60%	
Λ = 2, CI = 0, CR = 0			
Sub Criteria Physical	Slope	15%	40%
	Land Height	4%	
	Type of soil	3%	
	Land Cover	11%	
	Flood History	7%	
Λ = 5.06, CI = 0.015, CR = 0.013			
Sub Criteria Hydrology	Rainfall	0.5	60%
	River Density	0.1	
Λ = 2, CI = 0, CR = 0			

Fig. 2. The results of weighting the flood hazard using the AHP method by Ramadhani et al. (2022)

The input data for the AHP method uses experts' opinions as sources, namely the City engineering officer, City planning officer, Provincial Director of the

environment and natural resources office, and Director of the Integrated Coastal Resource and Management Program of Davao Oriental. The weight assessment of the AHP method shows that rainfall and slope are the most influential causal factors for the occurrence of pluvial floods in AHP. Meanwhile, in the Maxent model, elevation and rainfall are the most influential factors. Another assessment from the research of Ryka et al. (2022) found that rainfall was the most influential factor in determining flood vulnerability in Central Balikpapan, followed by the criteria for distance from the river, slope, and land use.

Table 1. Flood assessment literature

Author (Year)	Sources/ informants score assessors interviewed	Scoring and weighting criteria used
Ramadhani et al. (2022)	1. BAPPEDA Malang City employees. 2. Malang City DPUPRPKP employees. 3. Malang City BPBD employees.	1. Rainfall (50%) 2. Slopes (15%) 3. Land cover (11%) 4. River density (10%) 5. Flood history (7%) 6. Land height (4%) 7. Soil type (3%)
Ulfiana et al. (2021)	1. Hydrotechnician 2. Geodesist 3. Geologist 4. Planning expert city area	1. Land use 2. Rainfall 3. Slopes 4. geological conditions
Haris et al. (2022)	7 People with a background in disaster, land/physical resources, and spatial planning.	1. Rainfall (31.4%) 2. Slope (30.5%) 3. Land use (21.8%) 4. Soil type (8.7%) 5. Elevation (7.5%)
Cabrera and Lee (2020)	1. City engineering officer. 2. City planning officer. 3. Provincial director of the environment and natural resources office. 4. Director of the Integrated Coastal Resource and Management Program of Davao Oriental.	1. Rainfall (42%) 2. Slopes (23%) 3. Elevation (15%) 4. Distance to main channel (10%) 5. Drainage (6%) 6. Soil type (4%)
Subahagio (2021)	Document Transcript	1. Rainfall (32%) 2. Land use (28%) 3. Flow density(17%) 4. Slope (14%) 5. Soil type (9%)
Ryka et al. (2022)	4 people who are experts in their fields.	1. Rainfall (62%) 2. Distance to River (15%) 3. Slope Slope (12%) 4. Land Use (11%)

Source: Data analysis, 2023

Based on the results of the description from the literature review and **Table 1**, as well as the results of discussions with the contributors of this paper, the AHP weighting in the potential flood hazard assessment in Hamparan Perak District, along with the criteria used is shown in the **Table 2** below:

Table 2. Criteria, and score of flood hazard

Criteria	Score (Scale 1-5)
Rainfall	4
Slopes	3
Type of soil	3
Distance from the River	3
Land Cover	2

Source: Data analysis, 2023

From the literature review above, the criteria for rainfall, slope, soil type, distance from the river and land cover were selected for potential flood hazard criteria. Rainfall and slope are the two criteria used in every scientific study. Rainfall is a criterion in every study that has the highest weight. This is in accordance with the opinions of experts and research rock unit, and vegetation cover **(Figure 3)**. Weighting is done by determining the importance scale that considers aspects of judgment or rationality. The results which state that hydrological aspects (rainfall and distance from rivers) significantly influence the occurrence of flooding Ramadhani et al. (2022). The slope is an important factor causing flooding because water will flow in areas with a significant slope angle and inundate lower and flatter areas. Therefore in this study, rainfall gets a score of 4 (four), and the slope and distance from the river get a score of 3 (three). The criteria for soil type also have high weight and are used in four of the six studies above, so they get a score of 3 (three). Land cover gets a score of 2 (two) or less important because it does not affect the characteristics of the study area.

3.2 Landslide assessment

Landslide hazard research and studies that use the opinion of experts have been widely used, especially in academic studies. The weighting of the landslide disaster criteria in the research of Budianta (2021) was carried out using an approach that changed the qualitative values on the land characteristics map to quantitative values. The weighting includes three parameters or criteria: slope, research of Bayuaji et al. (2016) used the opinions of BPBD staff and ESDM staff as input data for analyzing landslide-prone areas in Banjarnegara District. The

processed input data produces criteria for determining landslide vulnerability: slope as the most significant factor, geology, rainfall, and land use. The same criteria were used in the research by Isneni et al. (2020) using the opinions of experts in geological engineering, geodetic engineering and BPBD employees in Magelang Regency. Weighting is done using the most influential slope criteria, then rock type, rainfall and land cover.

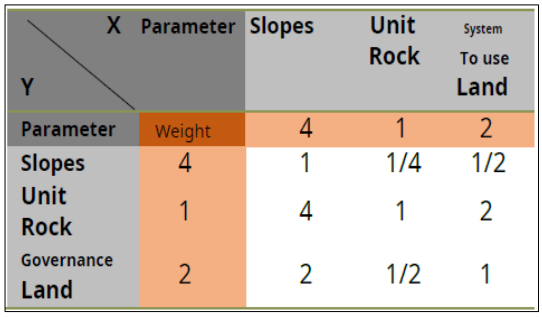

Fig. 3. The scale of importance on the weighting of landslide susceptibility by Budianta (2021)

Table 3. Landslide assessment literature

Author (Year)	Sources/ informants score assessors interviewed	Scoring and weighting criteria used
Budianta (2021)	Not mentioned	1. Slopes (4) 2. rock units (1) 3. Land use (2)
Kuncoro et al. (2021)	Not mentioned	1. Slope (53%) 2. Rock type (29%) 3. Alignment Density (12%) 4. Land Cover (6%)
Hardianto et al. (2020)	Puslittanak Model (2004)	1. Rainfall (30%) 2. Rock type (20%) 3. Slope (20%) 4. Land use (20%) 5. Soil type (10%)
Isneni et al. (2020)	1. Academics: Lecturer in Geology and Geodesy Engineering, Diponegoro University (2 people) 2. Stakeholders: District officials in Magelang Regency, volunteers, and BPBD staff in Magelang Regency (12 people)	1. Slope (36.6%) 2. Rock type (17.4%) 3. Rainfall (32.9%) 4. Land Cover (13.1%)
Khafid (2019)	Puslittanak Model (2004)	1. Rainfall (30%) 2. Rock type (20%) 3. Slope (20%) 4. Land use (20%) 5. Soil type (10%)
Bayuaji et al. (2016)	1. Banjarnegara Regency BPBD employee. 2. Banjarnegara District EMR Service Employee.	1. Slope (3) (45%) 2. Geology (3) (15%) 3. Rainfall (2) (36%) 4. Land use (2) (44%)

Source: Data analysis, 2023

Research on the AHP landslide disaster by Kuncoro et al. (2021), Khafid (2019), and Hardianto et al. (2020) was carried out based on the main geo-factor criteria for the threat of ground motion. These criteria are rock type, slope, slope distance to the structure and land cover. Kuncoro et al. (2021) weighted using the values from the geo-factor parameter comparison matrix from seven avalanche experts based on the results of a study by Ercanoglu et al. (2008). The weighting carried out by Khafid (2019) and Hardianto et al. (2020) refer to the 2004 Puslittanak Model with the highest weight criteria, namely rainfall, rock type, slope, land use and soil type.

Based on the results of the description from the literature review and **Table 3**, as well as the results of discussions with the contributors of this paper, the AHP weighting in the potential landslide hazard assessment in Hamparan Perak District, along with the criteria used is shown in the **Table 4** below.

This is in accordance with the results of Isneni et al. (2020) and Budianta (2021), where large slope angles dominate the high vulnerability zone. Based on the

Table 4. Criteria and score of landslide hazard

Criteria	Score (Scale 1-5)
Slopes	4
Rainfall	1
Land Cover	1
Type of soil	3
Rock Type	2

Source: Data analysis, 2023

From the literature review above, the criteria for slope, rainfall, land cover, soil type and rock type were selected for landslide hazard potential criteria. The slope is the most important factor and is given a score of 4 (four) according to each of the studies above, which use slope as the most important determining criterion in assessing landslide hazard. Large slope angles or steep morphological conditions, the existence of a watertight sliding plane in the soil subsurface layer, and groundwater above the impermeable layer are factors in the condition of an area where landslides occur (Karnawati et al., 2012). principle of the influence of criteria on the occurrence of disasters from several studies above, soil type is given a score of 3 (three), rock type is given a score

of 2 (two), and rainfall and land cover are given a score of 1 (one) each.

3.3 Tornado assessment

Only a little has been done to assess the potential, vulnerability and risk of a tornado disaster, especially those using the AHP approach. The research in the following literature does not use experts' opinions but uses provisions in accordance with existing regulations found by the authors. Research conducted by Wahyuningtyas and Pratomo (2015) which identified the potential for tornado hazard, found that the most significant rainfall criterion factor influencing potential disasters was followed by topography and land use. The weighting source used is the Guidelines for Final Aspects of the Minister of Public Works Regulation No.20/PRT/M/2007, which the researcher modified.

No.	Parameter	Sub-parameters	Weight	Class	Score
1	Rainfall	> 2,500mm/year	0.189	1	0.33
		2,001 – 2,500 mm/year		2	0.27
		1,501 – 2,000 mm/year		3	0.20
		1,001 – 1,500 mm/year ≤		4	0.13
		1,000 mm/year		5	0.07
2	surface temperature	31–35₀C	0.109	1	0.33
		26 – 30₀C		2	0.27
		36–40₀C		3	0.20
		21–25₀C		4	0.13
		≤ 20₀C and > 40₀C		5	0.07
3	Slope	0 – 8%	0.351	1	0.33
		> 8 – 15%		2	0.27
		> 15 – 25%		3	0.20
		> 25 – 45%		4	0.13
		>45%		5	0.07
4	land cover	Open ground	0.351	1	0.33
		Fields, meadows		2	0.27
		Shrubs		3	0.20
		Plantations, settlements		4	0.13
		Forest, body of water		5	0.07

Fig. 4. Tornado hazard weighting using the AHP method by Syafitri et al. (2021)

Research by Darmawan et al. (2020) conducted a scoring and weighting that refers to PERKA (Head Regulation) BNPB number 02 of 2012 to map the vulnerability of a tornado disaster. The results of the analysis and weighting show that the slope, land cover, and high rainfall are influential factors for the high risk of tornadoes in Humbahas District. Syafitri et al. (2021) used almost the same criteria in the research. In this study, the hazard of a tornado was influenced by several physical characteristics, namely slope, land cover, rainfall and surface temperature. The weighting, as shown in **Figure 4**, refers to the formula found by Davidson and Shah in 1997, sourced from the documentary transcripts found by researchers based on literature studies.

Table 5. Tornado assessment literature

Author (Year)	Sources/Informants score assessors interviewed	Scoring and weighting criteria used
Wahyuningtyas and Pratomo (2015)	Guidelines for Final Aspects of Regulation of the Minister of Public Works No.20/PRT/M/2007 with Modifications	1. Rainfall (40%) 2. Slope (35%) 3. Land use (25%)
Darmawan et al. (2020)	PERKA (Head Regulation) BNPB number 02 of 2012	1. Rainfall (33.3%) 2. Land cover (33.3%) 3. Slope (33.3%)
Syafitri et al. (2021)	Documentation transcript (Davidson and Shah, 1997) with modification by authors	1. Slope (35.1%) 2. Land cover (35.1%) 3. Rainfall (18.9%) 4. Surface temperature (10.9%)

Source: Data analysis, 2023

Based on the results of the description from the literature review and **Table 5**, as well as the results of discussions with the contributors of this paper, the AHP weighting in the potential tornado hazard assessment in Hamparan Perak District, along with the criteria used is shown in the **Table 6** below.

Table 6. Criteria and score of tornado hazard

Criteria	Score (Scale 1-5)
Slopes	4
Rainfall	4
Land Cover	3

Source: Data analysis, 2023

From the literature review above, the criteria for slope, rainfall and land cover were selected for potential tornado hazard criteria. Slope, rainfall and land cover were used in the three studies, which showed that these criteria significantly influenced the occurrence of a tornado. The slope and land cover is given a score of 4 (four) with the highest weight. This is in accordance with the results of research from Fadillah and Nurdin (2021) and Syafitri et al. (2021), which shows that areas with small slope angles, open land or settlements, and flat morphology have a high level of tornado hazard. Rainfall is given a score of 3 (three), referring to research by Syafitri et al. (2021), which shows that rainfall has an important enough scale for tornado vulnerability.

4. Conclusions

From the results of the analysis above, it can be concluded that the criteria and weighting scores for assessing the potential for flooding in Hamparan Perak District are rainfall (score 4), slope (score 3), soil type (score 3), distance from the river (score 3). and land cover (score 2). The criteria and weighting scores for assessing the potential for landslides in Hamparan Perak District are slope (score 4), rainfall (score 1), land cover (score 1), soil type (score 3) and rock type (score 2). The criteria and weighting scores for assessing the potential for a tornado disaster in Hamparan Perak District are slope (score 4), rainfall (score 4) and land cover (score 3). The criteria or variables of rainfall (hydrology), slope and land cover (physical) are the most significant factors influencing the three types of hydrometeorological hazards and disasters.

Recommendations

Further literature study research is needed on scoring and weighting other types of disaster hazards, especially those related to hydrometeorology. Grouping the types of disaster locations based on geographical and topographical conditions can also be done to make the results obtained more relevant.

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