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Conference Paper

Analysis of the Threat of Floods in Kendal Regency Using Fuzzy Analytic Hierarchy Process and the Geo Hazard Map Methodology Catalog

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Abstract

Based on BPBD (2018), Kendal Regency in 2017 have occurred 154 hazards, that are 30 floods, 19 landslides, 18 fire hazards, 20 stormwind, 13 marine accidents, and 54 other hazards. Most of the Kendal Regency area is dominated by floods hazard. Disaster management can be followed up with the initial stage in mapping of hazard threats. The methods that used in mapping of hazard threats are varied depending on the hazard parameters used. In this study, using two methods to analyze the threat of floods using Fuzzy Analytic Hierarchy Process and The Geo Hazard Map Methodology Catalog. Analytic Hierarchy Process (AHP) is a decision support method to determine priority of hierarchy with the main input based on experts. Fuzzy Analytic Hierarchy Process is an Analytic Hierarchy Process (AHP) method, that developed with fuzzy logic theory, especially triangular fuzzy which is expected to minimize uncertainty so that the results wpuld be more accurate. The results in this study can be used as input for the authorities to undertake preventive hazards management.

Keywords: fuzzy analytical hierarchy process, flood, kendal regency

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1. Introduction

Kendal Regency is one of regencies in Central Java Province that consists of the mountain area located in the southern part with altitudes up to 2,579 m above sea level and the temperatures ranged from 25^0C. Hilly areas located in the middle and the lowlands and coast in the north with an altitude between 0 to 10 m above sea level and temperature around 27^0 C. Kendal Regency is a regency where most of it regions is an agricultural areas. The land area in Kendal Regency is used for 26% of paddy land, 20% of dry field, 8% of plantations and 46% other landuse. Kendal Regency in 2017 have occurred 154 hazards, that are 30 floods, 19 landslides, 18 fire hazards, 20 stormwind, 13 marine accidents and 54 other hazards which have increased

compared with the previous year in 2016, where have occurred 9 floods hazard and 12 landslides based on BPBD, 2018. The hazards can have a physical environmental impact so disaster management is needed to reduce the damage caused by the hazards. Most of the Kendal Regency areas is dominated by floods hazard. Disaster management can be followed up with the initial stage in mapping of hazard threats. The methods that used in mapping of hazard threats are varied depending on the hazard parameters used.

Flood hazard can also occured because of the water discharge or volume of water flows in a river or drainage channel exceeds or above its drainage capacity [1]. According to the mapping methodology of hazard areas and flood potentials [2], the criteria affecting flood hazard are elevation, land use, rainfall, and inundation. The plantations land use, rice fields, forests and fields are a catchment area so that these areas can minimize the occurrence of river overflows that will cause flooding [3]. The lowland area that form of basins prone to floods due to rain water will gather in the area and cause floods. Rainfall can cause flood, if it falls with high intensity, long duration, and occurs in large areas. The higher rainfall, the greater the possibility of floods and inundation in a long time in an area will cause floods too [4]. Inundation are caused by drainage channels that are not function properly due to rubbish, sedimentation and grass and dimensions of drainage channels are unable to drain rain water.

The parameters for mapping flood threats are based on The Geo Hazard Map Methodology Catalog [2], but the weights used for each parameter in this study are assessed by two methods using Fuzzy Analytic Hierarchy Process and The Geo Hazard Map Methodology Catalog. The weight for flood threats based on The Geo Hazard Map Methodology Catalog is 0.25 for each parameter. The weight value indicate that the effect value of each parameter on the value of hazard threat. Similar to the Fuzzy Analytic Hierarchy Process method, the weight in each parameter of each hazards are different, based on the results of interviews with several related agency, that are from the (Department of Public Works) PUPR Kendal Regency and (Region Disaster Relief Agency) BPBD Kendal Regency. Analytic Hierarchy Process (AHP) is a decision support method in determining hierarchical priorities with the main input of experts or experts. Fuzzy Analytic Hierarchy Process is an Analytic Hierarchy Process (AHP) method developed with fuzzy logic theory, specifically triangular fuzzy which is expected to be able to minimize uncertainty so that the results obtained are more accurate [5].

2. Methods and Equipment

2.1. Methods

2.1.1. Fuzzy Analytic Hierarchy Process (FAHP)

The method used in this study is spatial analysis with scoring from the parameters of each criteria hazards based on The Geo Hazard Map Methodology Catalog. The weighting method for each hazard using the Fuzzy Analytic Hierarchy Process method. According to Analytic Hierarchy Process (AHP) is a method of decision making and a measurement theory, that used to measure ratio scales, both from discrete and continuous paired comparisons [6]. Fuzzy logic is a logic that has a value of obscurity or fuzziness between two values. The fuzzy approach, especially the triangular fuzzy approach to the AHP scale, is expected to be able to minimize uncertainty value, so that the results are more accurate [6]. The processing stages in the Fuzzy Analytic Hierarchy Process [6] are as follows:

1. If the results of the Consistency Ratio meet CR <0.100 [7], the weight of the pairwise comparison assessments on the AHP scale is changed into a triangular fuzzy number, which consist of components l, m, and u. The Fuzzy membership functions can be seen in the Table 1.

Table 1: The Fuzzy membership functions.

AHP Scale	Fuzzy Scale	Fuzzy Scale Invers	Definition
1	(1, 1, 1)	(1, 1, 1)	Equally Important
2	(1/2, 1, 3/2)	(2/3. 1, 2)	Middle
3	(1, 3/2, 2)	(1/2, 2/3, 1)	A Little More Important
4	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)	Middle
5	(2, 5/2, 3)	(1/3, 2/5, 1/2)	More Important
6	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)	Middle
7	(3, 7/2, 4)	(1/4, 2/7, 1/3)	Very Important
8	(7/2, 4, 9/2)	(2/9, 1/4, 2/7)	Middle
9	(4, 9/2, 9/2)	(2/9, 2/9, 1/4)	Absolutely More Important

2. Determine The Value of Fuzzy Synthetic Extent for each criteria and sub criteria, using the following equation:

$$Si = \oplus_{j=1}^{m} M_{gi}^{j} \bigotimes \left[\oplus_{i=1}^{n} \oplus_{j=1}^{m} M_{gi}^{j} \right]^{-1} \quad (1)$$

where Si is the value of fuzzy synthetic extent, $\oplus_{j=1}^{m} M_{gi}^{j}$ is addition operations on each triangular fuzzy number in each row, and $\oplus_{i=1}^{n} \oplus_{j=1}^{m} M_{gi}^{j}$ is addition operation for all triangular fuzzy numbers in each column of pairwise comparison matrix components.

3. Comparing The Value of Fuzzy Synthetic Extent (Si≥Sk), by the expressions:

$$V\left(S_2 \geq S_1\right) = \begin{cases} 1, & \text{if} \quad m_2 \geq m_1 \\ 0, & \text{if} \quad l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{others} \end{cases} \tag{2}$$

where $V\left(S_2 \geq S_1\right)$ is fuzzy synthetic extent comparison value, l_1, m_1, u_1 is the triangular fuzz component of the fuzzy synthetic extent comparison and l_2, m_2, u_2 is the triangular fuzz components of the fuzzy synthetic extent are compared.

4. Determine the minimum value of The Value of Fuzzy Synthetic Extent, by the expressions:

$$d'i = minV(S_2 \geq S_1) \tag{3}$$

where $d'i$ is FAHP weight value and $min\ V\left(S_2 \geq S_1\right)$ is the comparison value of the lowest fuzzy synthetic extent.

5. Calculating the normality of the weight vector and the minimum value to obtain the value of each criteria, using the following equation, so that priority is obtained from these criteria.

$$d_l = \frac{d'l}{\sum_{i=1}^{n} d'i} \tag{4}$$

Where d_l is normalization value of FAHP weights and $d'i$ is FAHP weight value.

3. Results and Discussion

3.1. The Threat of Flood Using FAHP and The Geo Hazard Map Methodology Catalog

The parameters that used to mapping flood threats in this study are the elevation, land use, rainfall, and inundation, according to The Geo Hazard Map Methodology Catalog. The elevation of the study area is processed by a topographic map with a contour interval 6.25 m and interpolated to DEM by the kriging method. Land use data are based on land use map in Urban Land use Plan Kendal Regency. The rainfall map is obtained from the monthly rainfall for a year in 2017 which is observed from 10

rainfall observation stations. The stations are located in Sukorejo, Patean, Singorojo, Limbangan, Kaliwungu, Patebon, Pageruyung, Pengandon, Sikopek and Weleri. The rainfall map is made by interpolation with thiessen method of rainfall data at rainfall observation stations in Kendal Regency. Water puddle data or inundation data was obtained from interviews with Department of Public Works (PUPR) Kendal Regency. Water puddle that occurred when floods in Kendal Regency come from the overflowing of Waridin River, Blorong River, Kendal River, Blind River, Blikar River, and Bodri River.

The results of flood threat map using the FAHP weighting method according to the results of interviews with several related agency, that are from the (Department of Public Works) PUPR Kendal Regency and (Region Disaster Relief Agency) BPBD Kendal Regency for the each parameter. The highest percentage of FAHP weights for flood threat is rainfall with a weight of 35.1%, so rainfall is the main priority parameter to determine the threat of flood in Kendal Regency. The second highest percentage of FAHP weights is the water puddle or inundation with a weight of 27.3%, so the water puddle or inundation is the second parameter priority to determine the threat of flood in Kendal Regency. The third highest percentage of FAHP weight is elevation with a weight of 21.1% and the smallest percentage of FAHP weights is land use with a weight of 16.5%, so land use becomes the last priority to determine the threat of flood in Kendal Regency. Whereas, The weight of each parameter to detemine flood threats based on The Geo Hazard Map Methodology Catalog is 0.25 for each parameter. The weight comparison between FAHP and The Geo Hazard Map Methodology Catalog are shown in Table 2, while the percentage of flood threat results in the area study based on both methods can be seen in Figure 1. In Figure 2 are shown the comparison of the results of flood threats in the area study using both methods.

Table 2: The weight comparison between FAHP and The Geo Hazard Map Methodology Catalog.

Parameters of Flood Threat	FAHP (%)	The Geo Hazard Map Methodology Catalog (%)
Inundation or Water Puddle	27.3	25
Rainfall	35.1	25
Elevation	21.1	25
Land Use	16.5	25

The level of flood threats in the area study are divided into 3 classes, where the highest percentage of flood threat classes with FAHP is the low threat class with 60.78 % threat class area (61,219,004 Ha) and spread across all districts in Kendal Regency. The moderate threat class with a percentage of 34,934% (35,190,008 Ha) that spread in 18 districts of 20 districts in Kendal Regency. The high threat class with

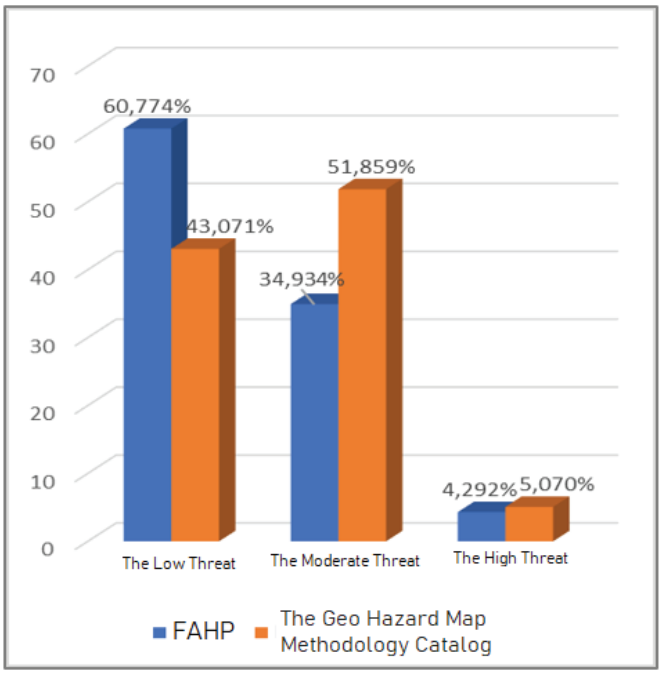
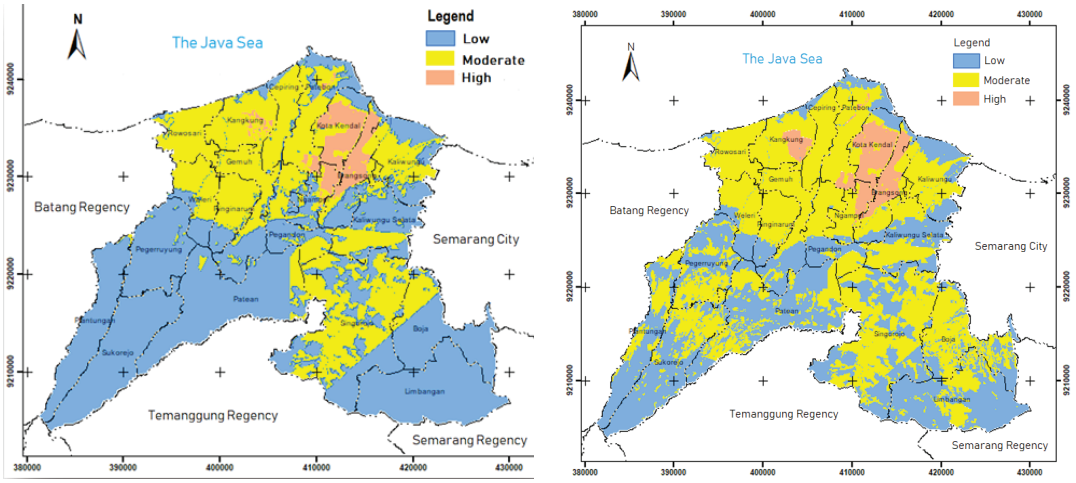


Figure 1: The Percentage of Flood Threat Results in Kendal Regency based on FAHP and The Geo Hazard Map Methodology Catalog Methods.

a percentage of 4,292% (4,323,897 Ha) that located in Brangsong District, Cepiring District, Kaliwungu District, Kaliwungu Selatan District., Kangkung District, (Kota Kendal) Kendal City and Patebon District. The highest percentage of flood threat class with Geo Hazard methodology weighting is the medium threat class with 51.859 % of threat area with 43,387,194 Ha are located in across all districts in Kendal Regency. The low threat class with a percentage of 43,071 % (35,190,008 Ha) and the high threat class with a percentage of 5,070 % (5,107,105 Ha) and located in Brangsong District, Cepiring District, Kaliwungu District, Kaliwungu Selatan District, Kangkung District, Kendal City, Ngampel District, Patebon District and Pegandon District.

The validation process in this study using cluster sampling method, where the sample population was limited to 10 districts in Kendal Regency are Brangsong District, Cepiring District, Kaliwungu District, South Kaliwungu District, Ngampel District, Pegandon District, Limbangan District, Kendal City, Singorojo District, and Patebon District. The sample in each districs randomly selected according to the guidelines of the disaster data from the BPBD Kendal Regency. Examples of the results of field validation in the high flood threat class can be seen in Figure 3. The results of processing with the two methods described previously were validated with field validation to obtain the validity of the processing results from both methods. Based on 40 samples, 30 samples were in accordance with the results of the processing flood threat by FAHP weighting



a b

Figure 2: The The Results of Flood Threats in Kendal Regency Using FAHP Weighting (a) and The Geo Hazard Map Methodology Catalog Weighting (b).

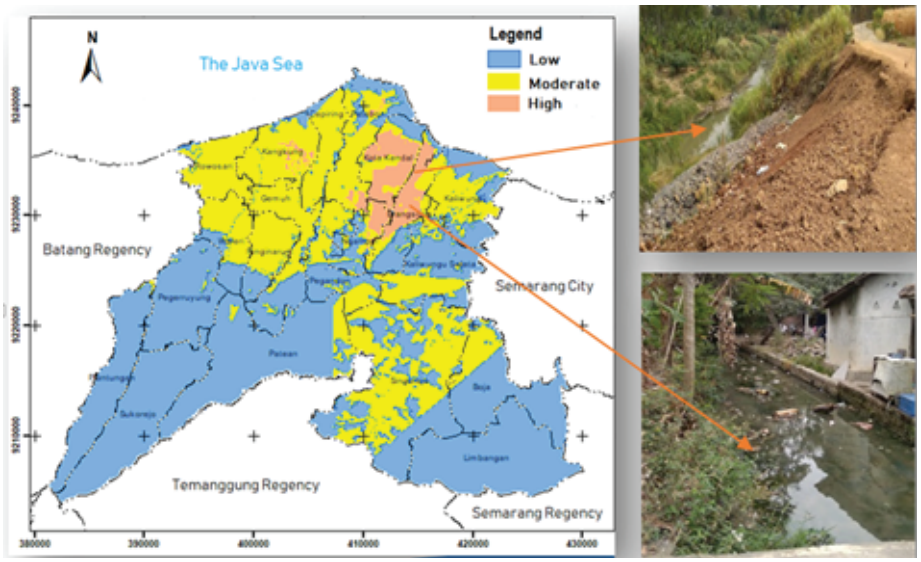


Figure 3: Examples of The Results of Field Validation in The High Flood Threat Class.

and 27 samples were in accordance with the processing of the flood threat by The Geo Hazard Methodology weighting. The conformity percentage in each flood threat mapping by FAHP weighting and Geo Hazard Methodology weighting is 75% and 67.5%. The discrepancy between the results of the flood threat map model and the sample of validation in the field is the existence of river normalization efforts and the making of embankments on river banks by the government and the community. Areas that are normally affected by floods are found on riverbanks or other waterways, areas with high rainfall, and areas with lower elevations than other areas.

4. Conclusion

The accuracy of the results to mapping flood threats in Kendal District using the FAHP weighting method is 75%, while the results of The Geo Hazard Methodology weighting is 67.5%. Based on the results of the validation, the mapping of flood threat by FAHP weighting has a higher percentage of conformity than the Geo Hazard Methodology weighting and the difference in percentage is 7.5 %. The results shown a very clear difference from the two methods in explaining the moderate and low threat class.

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