DETERMINING VARIABLE WEIGHT OF FLOOD VULNERABILITY SPATIAL MODEL IN PONTIANAK CITY BASED ON ANALYTIC HIERARCHY PROCESS (AHP)

Iin Arianti[1]., Soemarno[2]., Hasyim, W[3]., and Sulistyono, R.[4]
[1] *Doctoral Program of Environmental Science, Brawijaya University, Malang*
[2] *Department of Soil Science, Faculty of Agriculture, Brawijaya University, Malang, Indonesia*
[3] *Department of Regional and City Planning, Faculty of Engineering, Brawijaya University, Malang,*
[4] *Postgraduate Lecturer, Brawijaya University, Malang, Indonesia.*
Corresponden email: iin_arianti@yahoo.com

Abstract: *Pontianak is a unique city because it is surrounded by rivers, has a relatively flat land surface with an altitude of 0,5 – 1,0 m above sea level, and close to the estuary and peat soil. Pontianak also has experienced frequent flooding. Due to its position as the capital of West Kalimantan Province, it is necessary to have a comprehensive study regarding variables influential to floods.*
In order to determine variables influential to floods in Pontianak city, pairwise matrices questionnaires were used by two experts in the hydrometeorology field where the order of its influential value was arranged by using the Analytical Hierarchy Process (AHP) method.
The consistency value of the expert ratio 1 is 0.0163 while the expert 2 is 0.0161. The smallest consistency value which is according to expert 2 was selected. The ranking of variable weight is as follow: rainfall of 0.5487, land use of 0.2002, land slope of 0.1171, land cover of 0.0783 and the smallest is soil type of 0.0556.

Keywords: *floods, weight, variable, AHP*

I. INTRODUCTION

Flooding is a hydro-meteorological disaster, meaning it is a disaster caused by meteorological parameters. This hydro-meteorological disaster has a major impact on the social and economic conditions of the community. Considering the magnitude of the impact, community and government need to increase their readiness in facing the hydro-meteorological disasters for short, medium, and long terms.

The way to be prepared to face a disaster to begin with understands the physical condition of the area that is vulnerable to flood disaster. Flood-prone areas mean areas that are often affected by flooding. This will be a problem if the area or location of the flood covers urban areas, such as Pontianak City in West Kalimantan.

Pontianak is the capital of West Kalimantan Province. Pontianak is an urban area, the center of all activities such as office complexes, health services, education, trade and services, industry and settlement as well as land, sea, and air transportation activities are also found here.

II. RESULT AND DISCUSSION

2.1 Background

In general, flooding is a phenomenon where land that is usually dry (not swamp areas) becomes submerged by water, where this is caused by the high level of rainfall and topographic conditions of the region that are low to the basin. The occurrence of flood disasters is also caused by the low ability of soil infiltration, which makes the soil unable to absorb water. In addition, the occurrence of flooding can be caused by runoff overflowing and its volume exceeds the drainage capacity of the drainage system or river flow system (Seyhan, 1990).

Referring to the causes of flooding, the determination of flooding causes are including rainfall, slope, soil type, land cover, and land use. These causes are natural factors. I.e. factors that determined based on the physical condition of Pontianak City and these are variables forming spatial models in this study. Spatial model is a model of data that has spatial information, where spatial information is the main focus of the model itself.

Pontianak's climate is classified as tropical. There is significant rainfall throughout the year in Pontianak. Even the driest month still has a high number of rainfall. Rainfall can be defined as rainwater collected in a flat place that does not evaporate, does not penetrate and does not flow after the rain falls. Rainfall becomes a causal factor of flooding because the high numbers of rainfall means floods are easier to occur. The rainfall in Pontianak City is more than 3000 mm every year. This climate is considered to be Af (tropical rain forest climate) according to the Köppen-Geiger climate classification. The average temperature in Pontianak is 27.6 ° C.

Pontianak is an area located along the Kapuas lower watershed. One characteristics of the downstream watershed area is that a flat topography and a very small slope (≤ 8%). Pontianak City is a delta area or sedimentation zone and categorized into a flood prone area. The soil type consists of two types, i.e. alluvial and peat.

Land cover in Pontianak is divided into built or residential areas, mixed gardens, open land, water bodies, and clouds. The land use in Pontianak City is allocated into health facilities, sports, education, worship, government, culture and tourism, settlement, agriculture, green open space, animal husbandry, trade and services, industry, ports, terminals, PLTD and landfill.

Based on the physical condition of the land and climate, Pontianak is an area prone to flooding, so it is necessary to create a spatial model to determine the flood-prone areas in Pontianak as spatial data. Spatial data has a very significant role for the development of Pontianak City. The utilization of spatial data as a data source is an effective way to achieve development goals effectively and efficiently. With the availability of complete and spatially accurate data, it will improve the quality of urban development and reduce disaster hazards and risks, especially floods, in densely populated urban areas.

Spatial decision-making which often uses many variables must be challenged with the problem of determining the weight level of one variable to another variable that makes up the decision function. Decision makers usually have to weigh for each variable based on its significance or important value of the variable in question. These variables are then compared based on their influence or significance. Variables that have the highest weight are variables that greatly affect the incidence of flood in Pontianak, while the smallest weight shows variables which have little effect.

The determination of weight of each flood variable in Pontianak uses the Analytical Hierarchy Process (AHP) method. AHP is a measurement theory through a comparison between two paired criteria that depend on the assessment of expert opinion to get a priority scale (Saaty, 2008). The theory was developed by Thomas L. Saaty in 1970, and has undergone many improvements and developments until today. The advantage of AHP method is that it can provide a comprehensive and rational framework in structuring problems for making decision. In this study, the weight is used to determine variables which cause the flood and how much its influence based on the AHP method.

AHP helps in determining the priorities of several variables by conducting pairwise comparison analysis of each variable. The influence assessment of each variable compared was taken using pairwise comparison matrix based on the assessment of two (2) experts. The expert judgment was tested for its consistency. If the consistency value is <0.1, then it is accepted; as well as vice versa if the consistency value is > 0.1, then a re-evaluation is needed.

2.2 Determining Variable Weight of Flooding

2.2.1 Creating Matrices Pairwise Comparison

The procedure of pairwise comparisons assessment in AHP refers to an assessment score that has been developed by Thomas L. Saaty (2008), as follows:

Table 1. The fundamental scale of absolute numbers

Intensity of Importance	*Definition*	*Explanation*
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favour one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favour one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above non-zero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*	A reasonable assumption
1.1–1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

In the weighting or assessment of pairwise comparisons, the law of reciprocal axioms is applied, meaning that if an element of A is considered more essential (5) than element B, then B is more essential 1/5 compared to element A. If element A is as important as B then each value = 1.

In this study the matrix pairwise comparison was based on the assessment of two experts in hydrometeorology field with the following results:

Table 2. Pairwise comparison matrices expert 1

	R	LC	LU	SL	ST
R	1	9	3	3	5
LC		1	1/3	1/3	1/2
LU			1	1	3
SL				1	3
ST					1

Table 3. Pairwise comparison matrices expert 2

	R	LC	LU	SL	ST
R	1	7	3	5	9
LC		1	1/3	1/2	2
LU			1	2	3
SL				1	2
ST					1

With: R = Rainfall
LC = LandCover
LU = LandUse
SL = Slope
ST = Soil Type

2.2.3 Consistency test

Test the consistency of the two experts to choose which opinion is the most consistent, i.e. value of Consistency Index < 01. The consistency test stages are as follows:
Complete the pairwise comparison matrix of the above two experts by creating reciprocal matrices.

Table 4. Reciprocal matrices expert 1

	R	LC	LU	SL	ST
R	1	9	3	3	5
LC	1/9	1	1/3	1/3	1/2
LU	1/3	3	1	1	3
SL	1/3	3	1	1	3
ST	1/5	2	1/3	1/3	1
Σ	1.9778	18.0000	5.6667	5.6667	12.5000

Table 5. Reciprocal matrices expert 2

	R	LC	LU	SL	ST
R	1	7	3	5	9
LC	1/7	1	1/3	1/2	2
LU	1/3	3	1	2	3
SL	1/5	2	1/2	1	2
ST	1/9	1/2	1/3	1/2	1
Σ	1.7873	13.5000	5.1667	9.0000	17.0000

Create Normalized Weight Matrices by dividing each matrix element by the number of each column. Add the elements for each row, the eigenvector can be calculated by dividing the number of elements rows divided by the number of variables.

Table 6. Normalized weight matrices expert 1

	R	LC	LU	SL	ST	Σ	Eigen Vector
R	0.5056	0.5000	0.5294	0.5294	0.4000	2.4644	0.4929
LC	0.0562	0.0556	0.0588	0.0588	0.0400	0.2694	0.0539
LU	0.1685	0.1667	0.1765	0.1765	0.2400	0.9281	0.1856
SL	0.1685	0.1667	0.1765	0.1765	0.2400	0.9281	0.1856
ST	0.1011	0.1111	0.0588	0.0588	0.0800	0.4099	0.0820

Calculate the biggest Eigen value, λmax by multiplying the number of values for each column in the reciprocal matrices with each Eigen vector.

$$[1.9778 \quad 18.0000 \quad 5.6667 \quad 5.6667 \quad 12.5000] * \begin{bmatrix} 0.4929 \\ 0.0539 \\ 0.1856 \\ 0.1856 \\ 0.0821 \end{bmatrix} = [5.0731]$$

λ_{max}= 5.0731

Calculate the Consistency Index, $CI = \frac{\lambda_{max}-n}{n-1} = \frac{5.0731-5}{5-1} = 0.0183$

The Random Index value is as follows:

Table 7. Random Index

N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.53	1.56	1.57	1.59

Because the number of variables is 5, n = 5, then RI value = 1.12

Calculate the Consistency Ratio, CR. $CR = \frac{CI}{RI} = \frac{0.0183}{1.12} = 0.0163$

Table 8. Normalized weight matrices expert 2

	R	LC	LU	SL	ST	Σ	Eigen Vector
R	0.5595	0.5185	0.5806	0.5556	0.5294	2.7436	0.5487
LC	0.0799	0.0741	0.0645	0.0556	0.1176	0.3917	0.0783
LU	0.1865	0.2222	0.1935	0.2222	0.1765	1.0010	0.2002
SL	0.1119	0.1481	0.0968	0.1111	0.1176	0.5856	0.1171
ST	0.0622	0.0370	0.0645	0.0556	0.0588	0.2781	0.0556

Calculate the biggest Eigen Value, λmax by multiplying the number of values for each column in the reciprocal matrices with each Eigen vector

$$[1.7873 \quad 13.5000 \quad 5.1667 \quad 9.0000 \quad 17.0000] * \begin{bmatrix} 0.5487 \\ 0.0783 \\ 0.2002 \\ 0.1171 \\ 0.0556 \end{bmatrix} = [5.0723]$$

λ_{max}= 5.0723

Calculate the Consistency Index, $CI = \frac{\lambda_{max}-n}{n-1} = \frac{5.0723-5}{5-1} = 0.0181$

Calculate the Consistency Ratio, CR. $CR = \frac{CI}{RI} = \frac{0.0181}{1.12} = 0.0161$

III. CONCLUSION

Based on the consistency test for experts 1 and 2, the results showed that the two experts gave a consistent assessment towards the pairwise comparison matrix that compare the effect of each variable forming the model of the flood vulnerability of Pontianak City. The consistency value ratio of expert 1 is 0.0163, while expert 2 is 0.0161. The ranking of flood variable weights from expert 1 is: Rainfall of 0.4929, land use and slope of 0.1856, soil type of 0.0821 and the smallest weight is land cover of 0.0539. The ranking of flood variable weights according to expert 2 is: rainfall of 0.5487, land use of 0.2002, and land slope of 0.1171, land cover of 0.0783, and the smallest is soil type of 0.0556. The selected result which has the lowest consistency value is assessment made by expert 2.

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